TIEMEC '94

THE INTERNATIONAL EMERGENCY MANAGEMENT AND ENGINEERING CONFERENCE

Bridging the Gap Between Theory and Practice

Research and Applications

Edited by
James D. Sullivan
Suleyman Tufekci

IEEE Systems, Man, and Cybernetics Society

COMMISSION OF THE EUROPEAN COMMUNITIES

EUREKA

Association of the European Operational Research Societies

April 18-21, 1994
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James D. Sullivan
Optimal Systems, Inc.

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In cooperation with the IEEE System, Man, and Cybernetics Society; the Operations Research Society of America (ORSA); the Institute of Industrial Engineers (IIE); the Association of the European Operational Research Societies (EURO); the National Institute for Urban Search and Rescue;The University of Florida, College of Engineering; the EUREKA Program for Research and Development in Europe; the Directorate-General XIII (Telecommunication, Information Market and Exploitation of Research) and III (Industry) of the Commission of the European Communities, The International Emergency Management and Engineering Society presents

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April 18 - 21, 1994

Hollywood Beach, Florida, USA

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Preface

Welcome to the world of high technology tools for emergency management and engineering! Papers from 6 of the 7 continents are contained in this volume, and nearly every type of emergency imaginable is discussed. So, you might say we are global in geographic scope and universal in topical spectrum.

This is our first conference as an independent professional organization. For ten years we were the special interest group of a larger computer society. In 1993, we decided that we had grown up, and it was time to leave an old, familiar, and very comfortable home. But that decision was the correct one, because we have grown almost fifty percent this last year, and attracted more interest, both domestically and internationally, than ever before. In addition, the overall quality of the papers in this proceedings is better than ever before. Some other projects we are working on include special journal issues and a book series on emergency management and engineering.

Many long-time friends are back, and several new faces have joined us as well. We are particularly grateful that the U.S. Bureau of Mines, the Federal Emergency Management Agency, Ecole des Mines de Paris, CEMAGREF, and A/S Quasar Consultants have representatives at our 1994 conference once again. We are also glad that NOAA, USGS, both the Canadian and American Red Cross, and four U.S. National Laboratories will be represented. And if I had the time and the space, I would mention all of the other members of the TIEMES team. We are joined by a common interest in the mitigation of human suffering and death caused by disaster, a far stronger bond than any created by administrative means.

This conference did not happen by accident, if you will pardon the pun, but rather through a tremendous volunteer effort over this last year. Suleyman Tufekci handled a substantial portion of the local arrangements. He also spearheaded the effort to establish a quality newsletter, "*Carpe Diem!*", and is working on putting together one of our special journal issues. He sought and received in cooperation with status from ORSA, IIE, and the University of Florida. Al Wallace was responsible for in cooperation status from IEEE-SMC, Lois Clark McCoy for NI/USR, Yaron Shavit for CEC and Eureka, and Giampiero Beroggi for EURO. "In cooperation with" status has helped provide a great deal of prestige and credibility for such a young organization. Harald Drager has worked very hard in recruiting quality papers for the 1994 conference. And all the other contributions of the program committee members are gratefully acknowledged as well.

This year's proceedings is dedicated to Bob Sheets and the National Hurricane Center. The tireless efforts of Bob and everyone else who works there has saved untold lives. We come to count on highly accurate forecasting, tracking, and monitoring of hurricanes from the National Hurricane Center. And the men and women of the NHC have never let us down.

James D. Sullivan
Optimal Systems, Inc.

Introduction

We have come a long way from our humble beginning. After establishing The International Emergency Management and Engineering Society (TIEMES), we began publishing our official newsletter "*Carpe Diem!*". And now, the first International Emergency Management and Engineering Conference, TIEMEC '94, is a reality.

The membership of TIEMES is growing rapidly. Global interest in Emergency Management and Engineering is clearly manifested in this proceedings volume of TIEMEC '94. We have over 60 papers, presentations and panels from 19 different countries scheduled during four days. Each of the contributors are practitioners or leading researchers in Emergency Management and Engineering. Each paper accepted for the proceedings has been reviewed by a panel of researchers with broad expertise in Emergency Management and Engineering.

Practically all types of emergencies are covered in this proceedings. As the theme of TIEMEC '94 puts it nicely, we intend to bridge the gap between the theory and practice of emergency management. With the rapid advancement of computers and communication technologies, very effective emergency management decision support systems are quickly emerging in the market. GIS, multimedia tools and powerful workstations are adding a new dimension to emergency management. You will find a wealth of papers and presentations in this volume that discuss these technologies.

In this volume, you will also find research and applications in emergency management from Australia, Brazil, Canada, Denmark, Egypt, England, France, Germany, Greece, Finland, Japan, India, the Netherlands, Norway, Romania, Russia, Slovenia, Switzerland, and the United States. This is truly an international gathering emphasizing the global importance of Emergency Management and Engineering. TIEMEC '94 also promotes cooperation between emergency managers and engineers around the world. Disasters are one common enemy which brings all countries together in a mutually beneficial alliance. Our goal is to contribute substantially to the formation of such a global alliance.

I would like to thank all the contributors and to our review panel for their efforts in bringing this proceedings volume to fruition.

I also would like to thank the TIEMES President Jim Sullivan for his unselfish and relentless efforts in bringing all these world-class researchers and practitioners to this conference. Without his full-time efforts, we would not have achieved the enormous success this conference has experienced.

Suleyman Tufekci
Program Chair

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Hurricanes and Their Impacts:
What We Have Learned From Past Experiences
and How Have Lessons Been Applied

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GEOGRAPHIC INFORMATION SYSTEMS IN EMERGENCY MANAGEMENT

USING GIS FOR HAZARDS VULNERABILITY ANALYSIS

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ABSTRACT

South Florida is considered one of the most hurricane prone areas in the nation and warrants a comprehensive and well-maintained hazards vulnerability analysis. As part of an effort to develop a long-range post-disaster redevelopment plan, an initial hazards vulnerability analysis was completed for Palm Beach County, Florida using a Geographic Information System (GIS). This paper provides a discussion of this experience. Hazards vulnerability analysis is the process of determining the degree to which population, property, environment and social and economic activity are at risk. It is recognized that a high level of prediction accuracy about time, place and magnitude of potential disasters is not likely to happen. A number of techniques are available for identifying and locating the extent of storm hazards. Those discussed include:

1. SLOSH (Sea, Lake and Overland Surge from Hurricanes) Model;
2. Flood Hazard Mapping;
3. Composite Hazard Maps and
4. Wind Damage Estimates

The justification for using GIS, it's strengths and shortcomings, data base requirements, limitations and examples of final products and their use are among the principal topics considered. As GIS becomes available to more local governments, emergency managers and town planners will be able to enhance their efforts to understand the magnitude and mitigate the potential damage of natural and man-made disasters.

*Contract with Palm Beach County, FL 33406

NATURAL HAZARDS IDENTIFIED

A number of hazards were identified for Palm Beach County. Those to be discussed include hurricanes and floods.

Hurricanes

The County is located on the Southeast coast of Florida. The Atlantic Ocean is contiguous to forty four miles of its eastern border. SLOSH Models have been conducted and used to define specific coastal areas which are considered vulnerable to storm surge. The entire 2,024 square miles within the County's boundaries are subject to the destructive forces created by hurricane velocity winds.

Floods

The terrain of Palm Beach County is relatively level. The eastern shores are at mean sea level and the mean elevation of the County is fifteen feet. Drainage problems are created by long periods of unusually heavy rainfall, after which the operation of locks and lift stations are insufficient to prevent floods in certain areas. All areas within the proximity of inland bodies of water and those areas below ten feet of elevation are subject to flash flooding or the pooling of water as a result of extensive rainfall.

METHODOLOGY

A number of existing techniques and data bases are available for identifying and locating the extent of storm hazards. These are discussed below.

SLOSH (Sea, Lake and Overland Surge from Hurricanes)Model

The National Weather Service has developed sophisticated computer models to estimate the predicted wind and surge effects of potential hurricanes. One of these that has already been applied to Palm Beach County is the SLOSH Model (Sea, Lake, Overland Surge, and Hurricane). The SLOSH Model differs from the models used to delineate flood zones under the National Flood Insurance Program (NFIP) in that it is non-probabilistic and does not assume a specified return frequency based on historical data (i.e., the 100-year flood zone).

Several steps are involved in applying the SLOSH Model to any coastline. First of all, the model must be "fitted" to the coastline under study. This means that it must be tailored to take into consideration the numerous specific natural and manmade features of the coastline which have some effect on surge penetration onto land. To do this, data are aggregated into grid areas overlaid onto the study area. The computer model is run for the area which results in a large number of scenario simulations based on different hurricane tracks, forward speeds, size and intensities. The Model produces output including (1) surface envelope of the highest surges above mean sea level; (2) time histories of surges at selected grid points; (3) computed windspeeds at selected grid points; and (4) computed wind directions at selected grid points.

Some of the most useful output for pre-disaster and recovery planning using GIS techniques are maps that indicate areas of maximum surge penetration under different intensity assumptions. Using different intensity and storm path projections, the SLOSH model generates generalized maximum water depth estimations. These estimations are used to produce inundation maps depicting the identification of areas particularly vulnerable to hurricane storm surge. Once this information can be digitally produced and entered into a GIS, spatial overlay analysis can estimate potential risks to different structure types.

Among the information items included on the SLOSH maps for Palm Beach County are:

- .Category 1 inundation area
- .Category 3 inundation area
- .Category 5 inundation area
- .Spot depth estimations for surge tide
- .Planimetric information such as roadways and hydrography

FLOOD HAZARDS

The National Flood Insurance Act, established by Congress in 1968, created the National Flood Insurance Program (NFIP) which provides property owners in floodplains with federally subsidized flood insurance in those areas which implement ordinances to reduce future flood losses.

Later, in 1973, Congress passed the Flood Disaster Protection Act making the purchase of flood insurance mandatory in special areas. The Federal Emergency Management Agency, who administers the NFIP, bases its studies on a definition of a 100-year flood event as a flood having a one per cent probability of being equalled or exceeded in any given year.

Local governments must agree to regulate new development in floodplain areas in a way which minimizes future flood losses. Flood Insurance Rate Maps (FIRM) are prepared by FEMA for this purpose. They show the one percent chance flood and detailed base flood elevation information. These maps become the basis for establishing insurance rates for floodplain property owners. They are an excellent source for flood hazard analysis once they are digitized. However, they are difficult to automate due to numerous map sheets produced at different scales, with different publication dates and out of date planimetric features.

COMPOSITE HAZARD MAPS AND DATA

Composite maps permit policy makers to view the cumulative effects of different elements of the hurricanes, coastal storm hazards and flood events, and to identify particularly hazardous locations. The polygon overlay and network capabilities of Geographic Information Systems (GIS) technology were very useful to develop the composite maps and associated attribute data.

Palm Beach County's Planning, Zoning and Building Department's GIS project was implemented in September of 1991 using ESRI's ARC/INFO and Intergraph's MGE/MGA software. As with all maturing GIS, a common problem is not having reliable digitized maps for detail site specific analysis. Due to timely procurement of a new SLOSH model with digital final products and a FEMA pilot project for digital flood zone maps, GIS coverages were available to start the analysis.

The only problem was the lack of parcel specific data or maps. To bypass this problem, aggregate data were used to estimate potential risk. By using aggregated unit counts from the Property Appraisor's records to run the overlay analysis, composite hazard maps were produced. Based on section/township/range summaries, the unit counts were linked to the SLOSH generated coverages by using the original survey section square mile grid. A similar approach was used to calculate the risk to 100-year flood events. Other useful coverages that were overlaid include critical facilities, current and future land uses and the transportation network.

Also, using GIS, tables were easily created containing the following information:

Section/Grid I.D.
(Range/Township/Section)
Total Single Family Units
Total Multi-family Units
Total Mobile Home Units
Total Subdivided Units
Residential Units
Grand Total Residential Units
Total Wind Damaged Units
Economic Code of Unit (Land Use)
Description
Count of Non-residential Units
Total Gross Floor Area
Total Value of Non-residential Units

Graphic information stored in the GIS includes:

Municipal Boundaries
Water Features

Vacant Land Areas
Section Boundaries
Critical Facilities
Planned Industrial Land Use
Planned Commercial Land Use
Categories 3 and 5 Hurricane
Storm Surge Boundaries
100-Flood Event Boundary

The general strategy used for calculating the percent of a section under the threat of a storm surge and flooding was as follows. First, GIS methods were used to calculate the percent of the storm surge area in each survey section. Second, the amount of the section devoted to municipal areas and water features was deleted. Due to the scope of work for the project, only the unincorporated areas were used in the calculations. The calculated result was the land area within each section under a hypothetical storm surge. Next, the section grid was linked to the aggregated unit count data bases to estimate the units at risk from the storm surge and flooding.

A series of maps and tables were prepared to show the vulnerability of Palm Beach County to storm surge and flooding. These maps should not be used to identify specific detailed geographic areas. They are prepared to provide County officials with a general order of magnitude of vulnerability based on an overall storm threat, not predictions of future events. In the future, the risk based on a hypothetical storm could be generated if specific factors of each individual type storm were modeled and more detailed mapping was available.

GIS was used to produce estimated residential structures and non-residential units at risk from a storm surge Category 5 hurricane and for a 100-year flood event in eastern Palm Beach County. The data is graphically shown by the township/range/section breakout. Approximately 29,000 units could be impacted by a storm surge and over 64,000 units in a flood event.

The composite maps indicate that the major concern from storm surge is in the northeastern corner of the County, around the City of Jupiter. This is due to the extensive area of land affected by the storm surge that flows up the Loxahatchee River and the amount of unincorporated land in north Palm Beach County.

A number of maps and tables have been produced to complete the Hazards Vulnerability Analysis for Palm Beach County. Among them are:

<u>Maps</u>

Residential units impacted by a 100-Year Flood

Critical facilities threatened by a storm surge

Commercial land impacted by a storm surge

Industrial land impacted by a storm surge

Index map of Range, Township and Section Numbers

<u>Tables</u>

Residential structures at risk from a Category 5 hurricane and a 100-year flood event

Number of structures damaged as a result of 140 m.p.h. winds

Number of non-residential units and gross square feet affected by a 140 m.p.h. wind speed by Section

Summary of agricultural acreage and values by type of crop affected by wind speeds of 140 m.p.h.

Map A.1.1, is shown as an example of the GIS output. It depicts a portion of the residential units at risk from a

Category 5 hurricane. Shadings indicate the impact area and severity of damage in percentage terms for sections.

One task that GIS analysis could not model was potential wind damage. Due to very specific sets of variables (i.e. storm track, wind field strength, wind direction, damage caused by projectiles, etc.) that effect wind damage by hurricane storm events, this task was meaningless for a pre-event analysis. During the time this project was being developed, the post-Andrew damage assessment results verified the difficulty in predicting wind damage.

In the future, more specific vulnerability analysis map products will be needed. Parcel specific mapping will be required to pinpoint special populations that will need help in evacuation procedures. Using network analysis techniques, the carrying capacities of roads can be used to model different evacuation scenarios. Temporary storm trash disposal sites can be planned, using GIS capabilities to lessen impact to well field zones and to the environmental sensitive lands. With detailed topographic information, roads and causeways that will be impacted by rising flood water can be identified and used in evacuation modeling. Also, what-if projections can be run to estimate impact from catastrophic events such as dike failures during a storm.

Reference

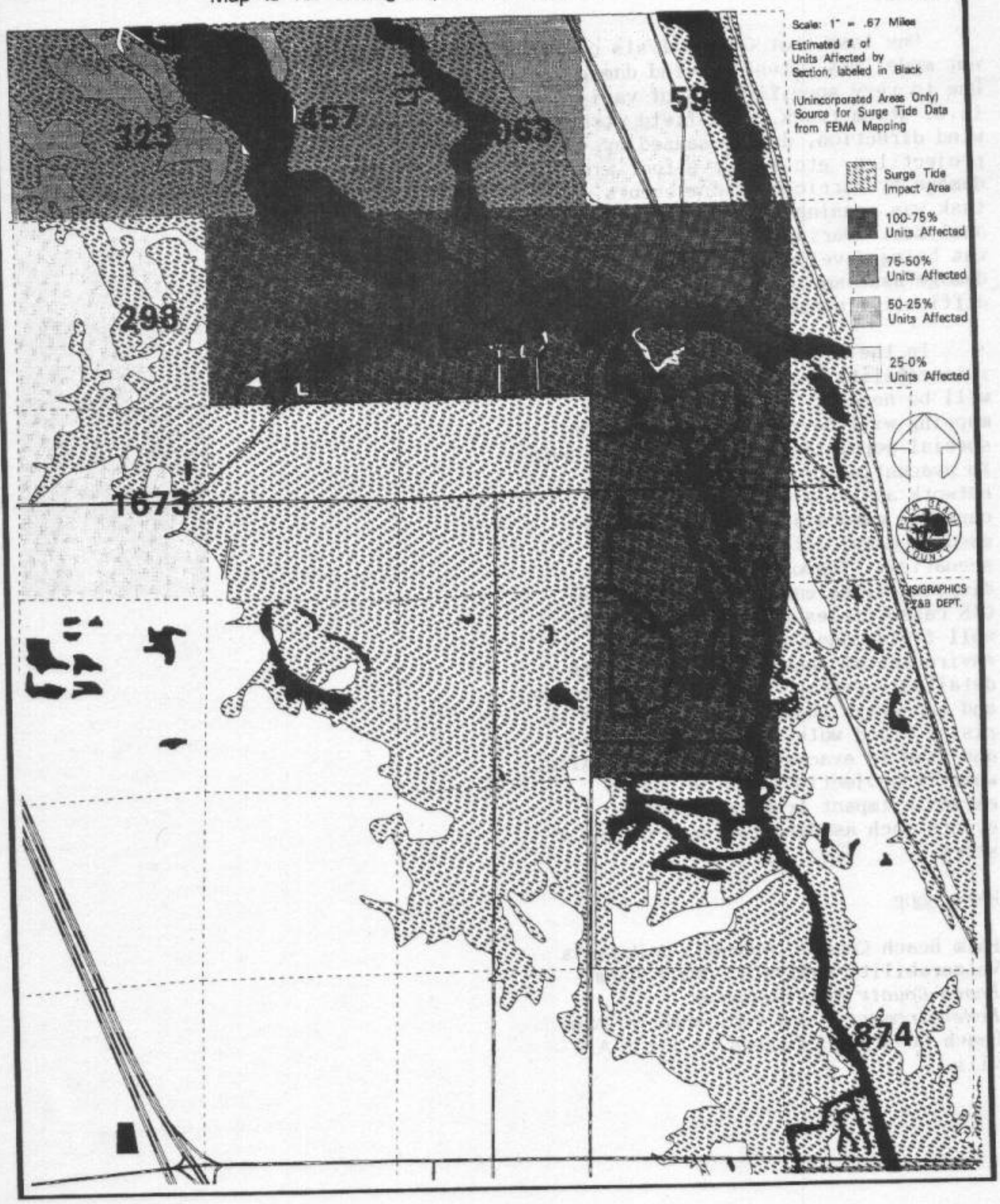
Palm Beach County, Appendix A Hazards Vulnerability Analysis, *Draft Palm Beach County Post-Disaster Redevelopment Plan*. Published by Palm Beach County, 1993, pgs. A.1 i - A.1 viii.

MAP A.1.1

RESIDENTIAL UNITS AT RISK FROM A CATEGORY 5 HURRICANE'S STORM SURGE

Map is for Emergency Plan Demonstration Only

Illust. 1



IMPROVING EMERGENCY PLANNING, PREPAREDNESS AND RESPONSE WITH GIS

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OVERVIEW OF EIS AND GIS

A Geographic Information System (GIS) is a multipurpose analytical tool that performs a seemingly endless variety of calculations to describe the geographic features of the earth. This includes natural and human systems, such as land use, roads, rivers, railroads, topography, building use, etc. The description of these features is both graphic (lines or areas on a map) and textual (short database entries designed by the user and "attached" to the lines or areas). Analyses performed include the selection of attributes (for example, how many electric utility transformers) located in a geographic area (called a polygon which might represent a zoning district); the calculation of how many of something (for example, utility poles) are needed to distribute evenly over a distance (measured by lines, sometimes called arcs, between two points, usually called nodes); and the determination of how long it will take a moving object (like a car) operating at a certain speed to traverse the roads (again, translated into lines on a computer screen) from one location (a node) to another. The key advantage of a GIS is that with the proper set-up of its analytical tools and with the proper data available, it will do just about any analysis conceivable. GIS strengths are in spatial analysis with the database and record-keeping systems required for textual applications a weakness.

The Emergency Information System (EIS) is a special purpose decision-support and record-keeping tool used to aid the performance of virtually every task required of corporate or governmental emergency, environmental, health & safety, security, and risk management decision-makers. The tools of EIS assist staff in the mitigation of hazardous conditions, preparedness for emergencies, response to incidents, and recovery from disasters. Regulatory compliance, specialized modeling, and integration with real-time communication and warning systems are its strengths.

EIS employs maps to assist in the spatial understanding of the requirements of emergency planning or decisions made during a crisis. Displayed on maps are all the geophysical features of the earth (roads, rivers, railroads, topography, land use, etc.) plus detailed graphic descriptions and representations of human structures (building floorplans, dams, airports, facility site plans, subway stations, and so on). Interacting with these maps are many custom datafiles which contain information traditional to emergency planning: event log, resource inventory, shelters, transportation, personnel, plans, chemical inventory, hazard analysis, and others. Each record in a datafile has "attached" to it a graphic representation consisting of one of more than 200 multi-colored icons, 16-color lines (solid, dashed, dotted), and circles or areas (with hollow, solid, or cross-hatched fill). These EIS graphics overlay the maps, blink selectively, easily change color, and can be juxtaposed in endless variety to display for decision-makers the geographic nature of the emergency. Using the on-screen pointer, any of these graphic overlays can quickly be expanded to show summary or complete information contained in the data record.

Significant analysis is part of EIS, including: what attributes (for example, nursing homes) are located in a geographic area, what the distance is along a road, what current resources are deployed, what actions have been completed in standard operating procedures, what are current weather conditions and forecasts, and the current inspection status for an infrastructure unit. Most important and critical to the decision-support capabilities of EIS is integral, multichannel communications. The product of any analysis can be flashed in seconds --- by telephone, cellular telephone, packet radio, or satellite --- to any other users in remote locations or even in moving vehicles. EIS gathers that critical data quickly from widespread sources and delivers it to key decision-makers.

In summary, GIS is a powerful analytical tool while EIS is a special focus action tool. Both GIS and EIS are extraordinarily valuable for emergency management agencies. GIS will provide planning information and analytical support that is not sensitive to short time requirements. EIS will translate GIS products into critical, time-sensitive, transactional and operational real-time decision-support information.

THE GIS INFORMATION MANAGEMENT CONCEPT

The basic concept of Geographic Information Systems is the establishment of "layers" of data which are geocoded to display in the right location when plotted by the computer. Using a common geocoding system (the most common being latitude and longitude), different types of data can be selectively layered together to create a map.

What the map becomes when created depends on the use being made of the data. Often, there are more than 30 different sets of data being maintained by a GIS department for its client departments and agencies. Any one of the clients can selectively pull out layers of data to create its own specialized map. A utility department may have the GIS department create a map of water, sewer, and gas lines with the street network being added for clarity. Or the local bus company may lay its bus stops on top of a street network showing only single lane streets that include traffic signals to study how stopped buses might affect traffic flow.

The concept behind GIS information management is that any or all data layers can be combined to make a map. In a sense, in GIS there is no such thing as a map, there are multiple layers of data, all of which are combined to complete the GIS analysis.

HOW EIS AND GIS WORK TOGETHER

The fundamental distinction in information management between GIS and EIS is that EIS maps are a composite of "layers" of information presented as one single display image on the computer. EIS maps usually consist of roads, rivers, railroads, and feature names. While GIS defines all its layers as data and any combination of data as a map, EIS clearly distinguishes between the map and its data overlays. The information management concepts of EIS and GIS differ in this specific regard.

That is because EIS is specific to emergency management applications while GIS must be all things to all people. Thus, a user in EIS can define exactly which layers should be combined in the digitizing process. From then on, every time a map is displayed, it has those layers. As a result, instead of the computer processing data layers for a minute or more every time a map is displayed, the EIS map with its predefined data layers intact is displayed in two or three seconds.

Thus, making EIS maps begins with the selection of GIS data layers and their combination into an EIS map. Importing digital cartographic data is done using a utility product called EIS/ARC (TM) which is a customized version of the leading GIS software, ARC/INFO (R). ARC/INFO gives us the capability of importing more than 20 GIS data formats, including TIGER, DLG, AutoCad (R), and Intergraph (R). Once imported into EIS/ARC, the EIS map is produced from data layers selected in consultation with the client.

MAKING EIS DATA OVERLAYS FROM GIS DATA

Other GIS data layers not used in the EIS map become EIS data. The EIS Data Import program translates the textual data into an EIS record format, interprets the GIS graphic into a corresponding EIS graphic that is "attached" to the EIS record, and then uses the GIS latitude/longitude data for exact registration of the data to its proper map location.

ADDING EIS DATA OVERLAYS FROM NON-GIS SOURCES

Because EIS is unique in its capacity to handle large volumes of textual data in a geographic environment, it has special capabilities to utilize data that has no place or role in a GIS. But, when incorporated into EIS, all such data optionally can have added to it graphic overlays. And, when graphic overlays are added, any data can be exported with latitude/longitude coordinates back to a GIS.

Among the different types of non-GIS data sources that are commonly used in EIS are:

Management Information Systems --- wordprocessing files, non-geographic databases, bibliographic retrieval systems, and others --- all can become part of EIS emergency decision-support systems. This means that extensive emergency plans and inventories can be quickly imported into EIS. And, geographic data overlays can be linked to non-geographic text data, making for a fully integrated management system.

Models and their results all can be integrated into EIS. Currently, EIS can dynamically incorporate real-time output from two different chemical air dispersion models, a radiological plume dispersion model, and an oil spill model. As well, the outputs from hurricane tracking and surge inundation models can be imported into EIS. Flood inundation model outputs for riverine flooding in both small and large urban areas have also been used in EIS.

Sensors are also available for real-time input to EIS. Sensor data is collected by any sensor system and EIS updates the sensor data in EIS. Sensor ranges can be set up to correspond with different colors or types of icons displaying on the EIS maps. Applications for sensor input to EIS include flood gauges, rain gauges, chemical detection sensors, motion and security sensors, radiation dosimeters, satellite-based tracking systems, and others. Thus, as the environment changes, sensors report the change, and EIS displays the changes by evaluating their impact and importance in real-time.

Communication sources of changing information are also part of EIS. Communication includes text messages sent from other users of EIS which, if they are important, can be added to the permanent EIS data records --- including attaching graphic overlays or icons to the message. Another type of critical information that is communicated into EIS is the National Weather Service Weather Wire. This satellite-delivered warning system is the official source for weather information in the U.S., and it is delivered into EIS computers.

Existing information resident in wordprocessors or spreadsheets are also easily added to EIS. Typing of lists and inventories into EIS databases is readily accomplished with little training. And, at the conclusion of entering each data record, the user has the option of adding a graphic that will form an overlay on the EIS maps. Graphic overlays can be added visually simply by moving the mouse to the proper location on the map and selecting the appropriate overlay graphic, or by entering the latitude/longitude coordinate, if it is known.

Any and all of this information tremendously adds to the capabilities of EIS to provide planning and decision-support to corporate and government emergency staff. The integration of these various forms of information, information that is completely unavailable in a GIS, is one of the hallmarks of EIS that make it a true, operational command, control, and communication systems for crisis decision-making.

USING EIS MAPS AND DATA FOR ANALYSIS AND DECISION-SUPPORT

Two methods provide analysis and decision-support in EIS, each of them operating with the quick response time necessary to handle large volumes of data fast enough to meet the needs of key executives. Because maps, geographic data, and non-geographic data are fully integrated and linked by EIS, the variety of retrieval and display options are exhaustive --- all designed to provide the right information at the right time in the right form.

Displaying EIS Geographic Overlays

The background map, defined by permanent layers of geographic information, has selectively added to it any EIS data overlays desired by the user. These overlays can be defined in several ways.

First, data records from a database can be retrieved. All records can be retrieved or records can be selected by matching text using boolean logic and functions to define the exact subset of data to be displayed.

Second, a multiple geographic area can be marked with any shaped polygon. Records can then be retrieved from the database (either all or through matching of text contained in the record) resulting in the display of records limited to the geographic areas marked with the polygon.

Third, multiple databases and combinations of the above retrieval methods can be used to display multiple and interacting EIS data overlays on EIS maps. This permits the clear depiction of spatial relationships of many different types of data to aid in decision-support. And, because EIS does not have to process the basic background map as data during the display process, the addition of EIS data overlays to the background map takes only a few seconds. Thus, the map and overlay display capabilities lend themselves to crisis decisions where seconds count --- and to executive briefings where seconds count just as much.

COMMUNICATION WITH EIS

Without a question, the distinction between GIS and EIS is most clearly made for emergency managers in the communication capabilities of EIS. Using telephone, cellular phone, packet radio, satellite, and FAX, EIS data quickly appears on other EIS computers anywhere in the world.

Communication is of two forms: free-form messages and data records (with the attached data overlays). Free-form messages function like an email system, allowing EIS users to broadcast a message to a number of others or target the message to another user. When a free-form message arrives, it can be pasted into the EIS Incident Log. And, when added as data, a graphic overlay can be quickly included with the data record to show the spatial relevance of the message.

Data records can be transmitted in the same broadcast or point-to-point format. When a data record arrives at another location, it can be viewed and thrown away or it can be added to the receiver's EIS database. When added, any graphic overlays included with the data record will automatically appear on the receiver's EIS maps.

The receiver does not have to be using EIS to receive messages. The communication program operates in the background, assuring reception of important messages and data even when being used for routine office work.

Transmission of data and messages can be classified in three priorities, each of which evokes a higher pitched and more frequent beeping when received. Together with the ability to carry out both broadcast and individual communication, these capabilities make EIS the most powerful emergency management data communication system available.

FAX communication is accomplished through the use of any Windows compatible FAX program. EIS map images (including appropriate data overlays) can be quickly faxed to any standard fax machine. Text listings and full record screens similarly can be delivered anywhere.

Real-time communication makes EIS unique among geographic information management systems.

Exchanging EIS Data with GIS

Data overlays in EIS are an extraordinary source of information for GIS departments. All emergency management information can be kept up-to-date on EIS and then transferred to the GIS department for inclusion in the GIS.

In a sense, this brings us full-circle. Data which was obtained from a GIS is maintained throughout the year by emergency management organizations. Then, when it is time for the GIS department to update its records, their job actually has become easier. No paper needs to be transferred. Rather, EIS outputs in a file format that can be read by all GISs.

Recall, as well, that non-geographic information can be added to EIS. All such data optionally can have added to it geographic overlays. And, when geographic overlays are added, any data can be exported with latitude/longitude coordinates. Thus, the GIS department has the opportunity to receive from EIS significantly more --- more accurate, more valuable, more current --- information than ever before.

EIS and GIS indeed are a value-added partnership for emergency management and GIS management organizations.

IN SUMMARY: GEOGRAPHY FOR COMMAND, CONTROL, AND COMMUNICATION

Every emergency management organization improves its performance, becomes more efficient, and protects lives and property better with the Emergency Information System. EIS is command, control, and communication for crisis decision support. It is also a valued resource for the development and maintenance of geographic information.

GIS is an extraordinarily valuable tool for emergency management spatial analysis. Any emergency management office would improve its analytical capabilities with a GIS.

However, GIS is no operational --- and does not try to be. GIS may even be a detriment in an emergency because the time allowed to perform a complex GIS analysis may prelude carrying out the actions determined by the analysis.

EIS, in turn, is operational but clearly lacks some of the analytical capabilities --- network analysis, transportation modeling, address matching --- that GIS was built to do.

EIS and GIS are not a case of either/or. It is a case of defining the needs of emergency management organization and beginning with the software that best meets those needs. If the needs are emergency management planning and operations, then the first choice is EIS. If the needs are for exhaustive spatial analysis, then the first choice is GIS. The products of those analyses then can be productively used in EIS for real-time response and planning.

EIS and GIS make for an unbeatable combination that should be standard operating procedures for every emergency management organization hoping to cope effectively with the complex hazards of the 21st Century.

For further information, contact EIS International, Suite 500, 1401 Rockville Pike, Rockville, Maryland 20852. Telephone: (301) 738-6900 FAX: (301) 738-1026.

USING A GIS PLATFORM FOR DESIGN AND ANALYSIS OF EMERGENCY RESPONSE OPERATIONS[1]

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ABSTRACT

Analytical models for optimization of emergency response operations in electric utilities study the effect of district designing and dispatching policies of the emergency repair units on the duration of the service interruption. A Geographic Information System (GIS) allows the efficient presentation of the analytical results and gives the capability to the end user to modify the assigned districts and evaluate variations to the proposed solutions. An off-the-shelf PC-based GIS system is used in our study. Different layers of the GIS allow for presentation of more or less detailed maps of the area depending on the decision to be evaluated. Trouble calls (tickets) carrying type, priority, and time information from available databases are overlayed on the map. Experience with the system has shown that it is user friendly, easily acceptable by the electric utility personnel and preferable to the computer outputs of the districting models.

INTRODUCTION

The continuous and uninterrupted supply of electricity is a very important criterion measuring the quality of services offered by an electric utility company. Usually, the quality of services is expressed by the Mean Number of Annual Down Hours (MNADH) per customer. Service unavailability has an adverse impact on the consumers and reflects negatively on the reliability performance of a given electric utility company.

[1]Work partially supported by Florida Rower and Light

The electricity availability can be increased by improving the design, the maintenance, and the restoration time of system failures.

This work focuses on the analysis and optimization of system reliability through the optimization of emergency response operations though the use of a GIS platform as an assistant to analytical models that have been previously developed[1].

DESCRIPTION OF THE SYSTEM

Definition of the problem

The demand for emergency repair services is created from incidents causing power interruptions. These incidents occur randomly in time and space. When a power interruption occurs one or more customers call a service center to report service unavailability. Based on the customers' calls a work order (ticket) is created by a computerized system, called in this particular application Trouble Call Management System (TCMS). This ticket is assigned to an emergency repair truck (ERT) for further investigation and repair. The ERTs are mobile servers and at the time of dispatch can be located anywhere within a designated repair district. The service area is divided into contiguous areas called districts which are further subdivided into truck areas. Trouble tickets carry priority, type and shift information. There are four priorities into the current system. A certain type of equipment failure may be of different priority depending on the severity of the failure. Tickets of higher priority are dispatched first. Dispatching of tickets in the same priority may follow First Come First Serve or Nearest Neighbor dispatching policy or a combination of the two.

Available data for the analysis of the problem need to be collected and carefully evaluated. The data must provide complete information on the operations. The number and type of tickets issued, the time it took for the corresponding response of the ticket, the geographical representation of the area and the distribution of the available equipment need to be documented. Once data are collected their quality must be evaluated and data that are corrupted should be excluded. This exclusion should be done very carefully since oftentimes large values of some parameters are the result of the peculiarities of some response situations and not a data entry error. The record of each trouble ticket had information about the date, day and time of that the ticket was created by TCMS. Every record also had information about the area that the ticket was located as well as the actual address of the incident. In addition the record had information about the location of the incident based on a proprietary grid system of the utility company. It also had the number of the truck that responded to call and codes about the shift and the type of the incident. Finally, each record had four time components, each one representing the time that needed for the ticket to be created by TCMS (T_0), the time that was needed for the ticket to be assigned to a troubleman (T_1), the time that the troubleman needed in order to arrive to the incident location (T_2), and finally the time required for fixing the problem (T_3).

In our previous work we have focussed on studying the effect of redistricting and ERT deployment policies on the reduction of the dispatching time T_1 and travel time T_2, since the repair and ticket assignment time depend on technical characteristics of the system and should be evaluated in a different way [1] .

In this work, the results of the districting and dispatching are made available to managers of emergency response operations through a GIS platform. This gives the opportunity to the managers to evaluate alternative scenarios, get appropriate statistical data and manipulate the results of the districting patterns to allow for districts that take into account peculiarities of the transportation network, the geography of the area and the corporate organizational structure in divisions other than the emergency response operations. Mahoney, R.P.[2] in his work "GIS and Utilities" gives a detail account of the advantages that GIS technology offers to utility companies in general and electric utilities in particular.

Geographic Information System Platform

The system consists of a software part and a data. The software part of the system has the following three components: i) Mapinfo™ for DOS, ii) TRALAINE™ and iii) programs that manage the integration of the various pieces. Mapinfo™ for DOS provides the geographic information system, and TRALAINE™ provides a system for conversion of the geographic coordinates from one system to another. The programs written in QuickBasic provide the conversion of the data from the proprietary system that the utility company used to a systemthat would allow TRALAINE™ to provide the conversion.

The second part of the information system is the data part. We integrated data from three different sources, i) map data for the required areas purchased from the U.S. Census Bureau(TIGER files), ii) data of the trouble tickets provided by the utility company, and iii) data created by the districting application. QuickBasic programs were required in order to transform the TIGER files to the format required by Mapinfo™[3], and also for conversion of the output of TRALAINE™[4] to the required format by Mapinfo™.

CAPABILITIES OF THE SYSTEM

The system capabilities can be divided in spatial analysis, and statistical analysis capabilities.

Spatial analysis capabilities.
The spatial analysis capability is a feature the utility company was not able to have before. By providing a visualization of the exact location of each trouble ticket, figure 1, the analysts of the company could identify patterns of trouble tickets and then try to explain the reason of such patterns.

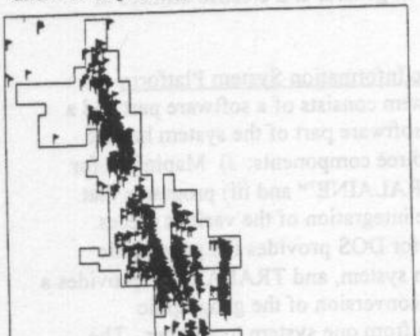

Figure 1: Tickets of all types

Especially the identification of the type of a trouble ticket could provide information about aging or faulty equipment which created frequent trouble tickets. Furthermore, reports generated by the system can include only part of the trouble ticket database based on criteria set up by the analyst using the system, figure 2 displays only transformer tickets.

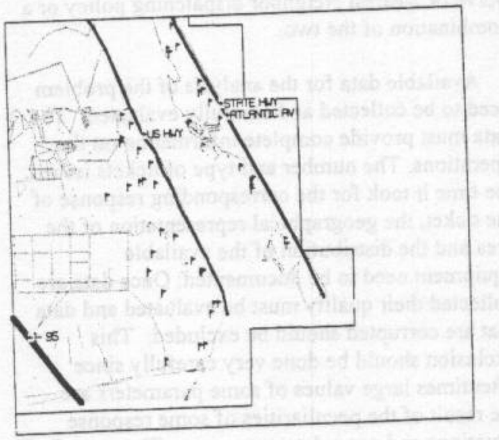

Figure 2: Transformer tickets (detail of the area)

Statistical analysis capabilities.
Improved visualization has helped the utility personell in their statistical analysis requirements. The various kinds of statisticalanalysis are: i) distribution of time for dispatch, arrival, and repair, and ii) number of tickets per area.

These two kinds of statistical analysis are very important because one of the concerns of the company is that all the trouble areas are balanced in the number of tickets as well as in area covered.

Dispatch time distribution   This piece of information is important, because the identifiable problem in the company was a bottleneck at the dispatch area. Provided that there are four dispatchers and each one is responsible for a couple of trouble areas a distribution of the dispatch time could provide insight into the problems of dispatching(figure 3).

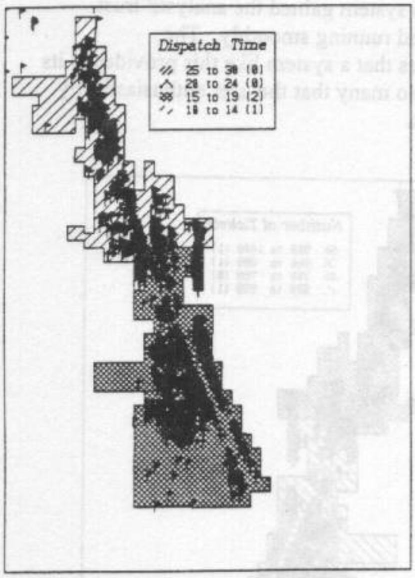

Figure 3: Dispatch time distribution

<u>Traveling time distribution</u> This information is important in order to verify that all areas are balanced in terms of time needed to arrive at the location of the trouble(figure 4). The company may set up its own time distribution classes and see how the proposed areas fit in them. Also based on the information of the shift, or other specific time periods, e.g. morning or afternoon rush hours, the analyst could see how the time distribution changes in a trouble-area, or in other specific zone, e.g. downtown compared to suburbs.

<u>Repair time distribution</u> This piece of information provides insight in terms of each individual troubleman. The analyst could identify differences in the time distribution between troublemen for a specific type of trouble, as well as the trouble tickets as a group(figure 5). Such information is important for identifying the stars among the troublemen in order to appreciate their effort as well as identifying troublemen needing retraining.

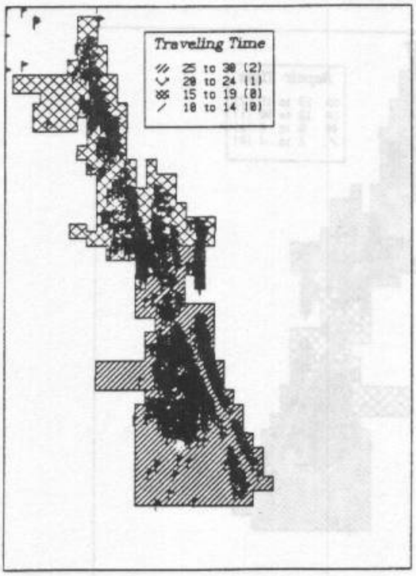

Figure 4: Traveling time distribution

<u>Number of tickets per area</u>. As mentioned earlier, part of the company's policy is to have balanced trouble-areas in terms of number of tickets or otherwise specified as workload. The distribution provided by this analysis would show the areas that are in different classes in the number of tickets as a whole(figure 6), or in the number of specific type of tickets. Combining this information with the information provided by the spatial analysis provides information about the areas that the troublemen work.

Another type of analysis that this system is particularly significant is the what-if analysis. The analysts of the company have the ability to change the shape of a trouble area and make it smaller or bigger and then perform the same type of analysis discussed earlier and compare the results. This is especially important for decision of reshaping the trouble areas in different time periods, e.g. late night to early morning shift, or in cases of special emergencies such as hurricanes etc.

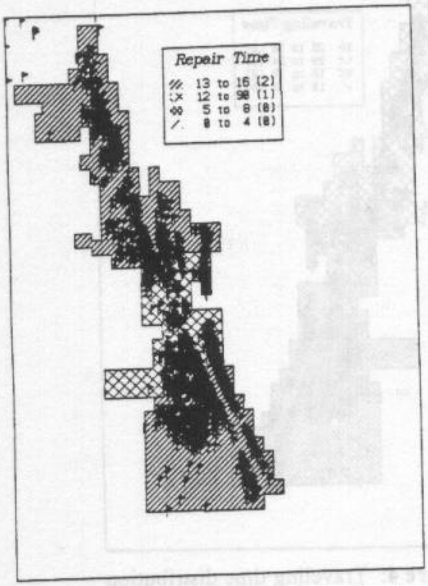

Figure 5: Repair time distribution

USER ACCEPTANCE.

The acceptance by the users was a major concern in the design of this application. For this reason the end-users were involved in this project from the beginning. Since the nature of the application was not job threatening for the end users of the application, but it was more a tool for the analysts in order to perform their task better and faster, their support was continuous and their interest was expressed by their active involvement in the development of this system.

The only problem that we faced was the unfamiliarity of the analysts with a system like that as well as the number of components of the systemthat the users had to learn. However, after a series of intensive training and as soon as the information system gained the analysts' trust things started running smoothly. The opportunities that a system like this provides to its users were so many that the user enthusiastically embraced it.

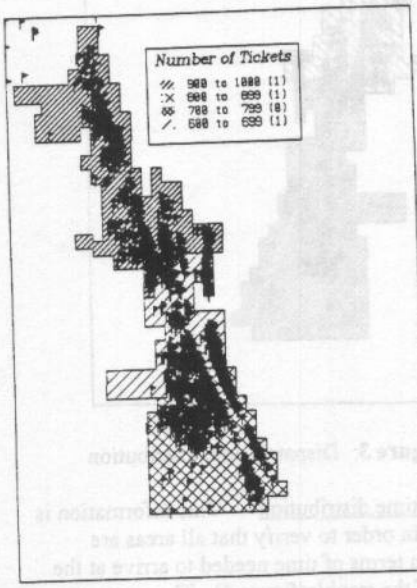

Figure 6: Ticket distribution across the area

CONCLUSIONS AND EXTENSIONS

The current information system has only the street network of the area under study. As was mentioned earlier problems in the distribution network of the utility could be easily identified by spatial analysis. However, after certain types of problems have been identified the analysts should look at the database with the information about the distribution network. The integration of this network in the geographic information system will be something that should naturally follow an endeavor like this one. Problems of information overload of the computer system should be minimal since the available technology provides for fast processors as well as hard drives with great capacity and very small access time.

Another area where this system may be enhanced is that for the moment the system is fed with off-the-line and after the fact information. An integration of such a system in the emergency response system of the company as well as the incorporation of Automated Vehicle Location (AVL) technology will improve the operation of the system greatly as suggested by K.G.Zografos and C.Douligeris in [5]

.

Finally one of the advantages of this system is that it allowed the users from the company to become familiar with a technology that may be proven very helpful in cases of disasters. The ability of the system to run under DOS and the availability of notebook personal computers with great capabilities allows for the system to be portable. Therefore, such a system could be used from people out in the fieldwhen the occasions of a disaster require so.

From our discussion we can conclude that an integrated geographic information system enhances the operation of a company by offering a great number of advantages. Such advantages are ability of spatial analysis, statistical analysis, and what-if analysis. Most of these kinds of analysis were not possible with any other system and provide a great advantage to the company.

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COMMUNICATION SYSTEMS IN EMERGENCY MANAGEMENT

ADVANCES IN MINE EMERGENCY COMMUNICATIONS

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ABSTRACT

Since 1981, Federal mining law has required every miner working in underground coal mines to have a self-contained, self-rescuer (SCSR) available for use in emergencies. Some miners that have escaped from fires using SCSR's have reported that they had to remove their mouthpiece to talk during escape, thus compromising the protection afforded by the SCSR. If miners are in thick smoke during an escape, they may have trouble if they become separated from their group. The visibility can be so poor that separation can occur at very short distances. To address this problem, two-way, FM radios were built into the SCSR to improve the ability to communicate should the miners be separated over relatively short distances.

The SCSR prototypes built and used in testing included both two-way radios and improved mouthpieces. Comparison studies were conducted using combinations of the new and old mouthpieces, and trials using the radio or not using the radio. Subjective judgements indicate that communication ability was significantly improved using the prototype devices.

Communication problems have been encountered with teams using standard voice-powered communications systems. Mine rescue teams perform rescue and recovery work under extremely hazardous conditions, life lines are a standard part of mine rescue team equipment. Leaky feeder and quasi-leaky feeder life line communications systems provide significant improvements over standard systems. These improved systems allow all members of the team to communicate with each other and their base of operations. These innovations will significantly enhance the safety of mine rescue operations.

INTRODUCTION

Since 1981, Federal mining law has required every miner working in underground coal mines to have a self-contained, self-rescuer (SCSR) available for use in emergencies. These devices provide a minimum of one hour of oxygen to escaping miners in the event of an emergency evacuation due to mine fires or explosions. Miners that have escaped from several recent mine fires using SCSR's have been interviewed, and some have reported that they had to remove their mouthpiece to talk during escape, thus compromising the protection afforded by the SCSR.

In September 1989, an explosion occurred at the Pyro Mining Company's No. 9 Slope, William Station Mine in Union County, Kentucky, resulting in the deaths of ten underground coal miners. Five of the nine persons who used filter-type self-rescuers (FSR's) while trying to escape the explosion area did not survive. According to the survivors, several of the victims removed their self-rescuers in an attempt to talk with each other. As a result of this incident, an MSHA report (1990) recommended that MSHA, in conjunction with the U. S. Bureau of Mines, should examine the feasibility for developing self-contained self-rescue devices which allow communication without removal of the mouthpiece.

Successful communication is critical during an emergency evacuation. Miners need to be able to communicate during escape in order to make decisions and to provide emotional support to one another in a life threatening situation. This requires a full range of two way speech. Simplified communications, such as cap lamp or hand signals, simply do not begin to provide the necessary psychological support, and decision making ability needed during a crisis.

SCSR Communication Problems and Solutions

The main problem in trying to communicate while wearing an SCSR is the mouthpiece. It interferes with normal speech in ways that are difficult to compensate for. The teeth and lips can not be brought together as they are in normal speech. This interferes particularly with words that contain "m" or "b" sounds. An improved mouthpiece was developed which helps to overcome the interference. Figure 1 is a photograph of the improved mouthpiece that was developed during a one year research effort. A speech pathologist and an oral surgeon were included in the team that designed the new mouthpiece. This part is more pliable, and considered by some using it, to be more comfortable. If miners are in thick smoke during an escape, they may have trouble if they become separated from their group. To address this problem, two-way, FM radios were built into the SCSR to improve the miner's ability to communicate at a distance. The effective range of this system is currently about 30 meters. Communication at this range without the radio is virtually impossible, with or without the improved mouthpiece. Figure 2 is a schematic diagram of an SCSR equipped with radio communications.

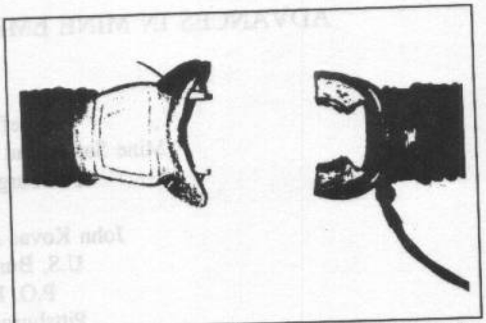

Figure 1.--New mouthpiece (left) vs standard mouthpiece

Subjective judgements indicate that communication ability is significantly improved using the prototype devices. It is still difficult to talk with the SCSR on; however, the situation is improved from the unmodified rescuer. Further studies will focus upon repackaging and improving the radios, and performing objective tests of speech clarity.

Life Line Communications Problems and Solutions

Mine rescue teams perform rescue and recovery work under extremely hazardous conditions. Federal law requires each operating mine to have ready access to at least two certified mine rescue teams. Only highly trained and motivated persons are permitted to work on these teams due to the demanding nature of their operations. Becoming separated from the team in limited visibility could be a fatal mistake when there is no other way to re-establish communications. Therefore, life lines are a

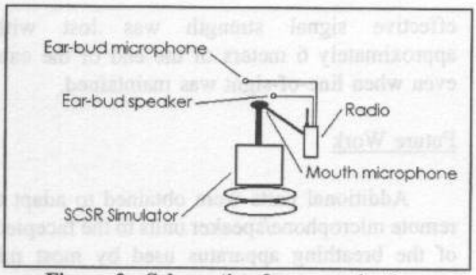

Figure 2.--Schematic of communications equipped SCSR

standard part of rescue and recovery operations. The type of life line used by the majority of mine rescue teams is a 300 meter section of a relatively thick cable that supports a sound-powered communications system. This cable is fed off a cable reel as the team advances. It is cumbersome to handle, often gets caught on obstacles, such as mining equipment, and it is difficult to pull over such equipment or around coal pillars (blocks of coal left during the mining operations to help support the mine roof). This type of communications system only allows one member of the team (the communications officer) to talk back to his base of operations (the fresh air base).

Standard leaky feeder cable systems have previously been investigated for use in mine rescue communications. Such systems were found to be too rigid and heavy. Mine rescue communications, however, could , in fact, benefit from the properties of a leaky feeder system. Such a system would allow all team members to talk to each other and the fresh air base.

Since the mine rescue team members are dependent upon their self-contained, breathing apparatus (SCBA) for survival, they cannot launch individual expeditions far afield from the rest of the team members. The only margin of safety that can be provided comes from remaining close to the others in the group along an established search path. Thus the range limitations of leaky feeder cable fall within boundaries that are already established by safety considerations.

Description of Equipment Used

A communication test was set up in the Bureau's Safety Research Coal Mine at Bruceton, PA, using Motorola MX330 hand-held radios, Radio Shack RG8 coaxial cable, and a yagi antenna. One of the radios was connected to the RG8 cable by an external antenna jack. The other two hand-held radios were operated without any physical connection to the cable. The RG8 cable acted as a quasi-leaky feeder.

The MX330 is an MSHA approved radio that can be used in explosive atmospheres. For the test, the radios were equipped with a remote microphone and a replaceable, approved, 3-hour, ni-cad battery. The radios operated on 464.5-469.5 MHz. The RG8 cable was divided into three, 75 meter sections, two 15 meter sections, and one 45 meter section to evaluate the convenience of carrying. Each end was equipped with an "N" type connector. The "N" type connector was selected because it makes a secure connection. It is screwed together and is water resistant. At each joint a "T" connector could be placed to allow for branching. The yagi antenna was placed on the end of one of the branched sections. The radios can be damaged by insufficient impedance in the antenna circuit. The yagi antenna provides this impedance load in addition to its broadcast function. Figure 3 is a schematic diagram of the equipment used during the in-mine tests of this system.

Results

The radios were taken into the mine to test the range without the assistance of the RG8 cable and antenna. The communications were clear and understandable as long as line-of-sight was

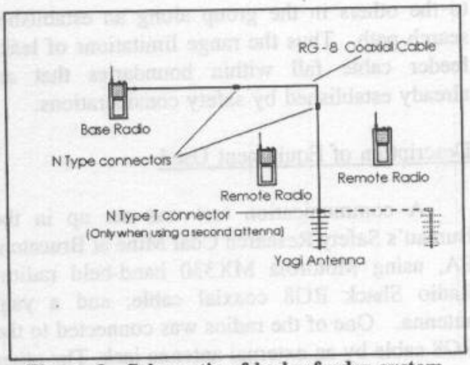

Figure 3.--Schematic of leaky feeder system

maintained between radios. Once line-of-sight was lost, the reception can be broken in as little as 6 meters from the line of sight.

In the next test situation, a single 75 meter length of cable was connected to the radio and the yagi antenna was connected to the end of the cable. This combination seemed to increased the effective distance in two ways. Not only was the distance between the two radios increased by the length of the cable, but the yagi antenna was a more efficient broadcast source/receiver than the built-in antenna. It was also found that the cable needed to by hung from the rib and not left lying on the mine floor in order to achieve acceptable results.

In the succeeding trials, the antenna was placed progressively closer to the base end of the cable as additional cable was added. The effect of adding cable was to reduce the signal strength at the remote antenna.

The final layout consisted of 225 meters of cable with the yagi antenna placed 75 meters from the base unit. In this configuration, communication away from the antenna, could be maintained as long as the cable was in the same entry as the remote radio. In this arrangement, effective signal strength was lost within approximately 6 meters of the end of the cable, even when line-of-sight was maintained.

Future Work

Additional parts were obtained to adapt the remote microphone/speaker units to the facepieces of the breathing apparatus used by most mine rescue teams. A final demonstration project will be conducted during a mine rescue exercise.

Conclusion

Two advances in mine emergency communications have been achieved. Prototypes have been built and tested; however, further testing, repackaging, and improvements must occur before both devices are made available to the mining industry.

Improvements necessary to complete the SCSR communications system are: 1) improvements in the radio, 2) miniaturization of the electronics packages, and 3) the electronics package must be made permissible (intrinsically safe or explosion proof, to be allowed to operate in an explosive methane-air environment).

Improvements necessary to complete the life line communications system include: 1) choosing an optimal frequency for operation, 2) making a final selection on a quasi-leaky feeder cable, 3) choosing optimal interfaces for SCBA devices, and 4) making the system permissible.

This technology will significantly enhance the safety of mine rescue operations. It possesses the potential of allowing rescue teams to operate more efficiently. The combination of security and increased efficiency should also allow for the use of fewer teams in some circumstances thus further reducing exposure to very hazardous environments.

USING LOW-EARTH-ORBIT SATELLITES TO PROVIDE EARLY-WARNING AND DISASTER-ASSESSMENT MESSAGING FOR EMERGENCY MANAGEMENT

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ABSTRACT: There is a need for warning of impending hazardous conditions and reliable assessment of post-disaster conditions as crucial elements in Emergency Management. Low-Earth-Orbit (LEO) satellite systems can fill this need by relaying status messages from small, low-cost, low-power transmitters, through LEO satellites, to control centers. Such systems are independent of common carrier communication systems and are resistant to disruption during disasters. An existing system, Argos, is already used for one-way messaging and geo-positioning in applications such as prediction of volcanic eruptions, indication of seismic station status, hydrographic station monitoring, and hazardous materials tracking. A specific case study of an existing system for early warning of volcanic eruption is presented. A new satellite system, Starsys, will soon provide two-way messaging and geo-positioning worldwide.

Introduction

North American Collection & Location by Satellite can now provide timely warning of increased volcanic activity to civil authorities and the airline industry. We are putting together a coalition of governments, international industries, and scientists to implement a simple system, low in cost, to allow monitoring of many volcanoes that pose a hazard to civil aviation and local populations.

For early warning of volcanic eruption to have much utility to aviation, monitoring must be done on many volcanoes. The cornerstone to such wide spread volcano monitoring is affordable instrumentation coupled with global coverage. We have developed affordable instrumentation that can be deployed anywhere in the world. This instrumentation uses the Argos satellite system as the telemetry link.

Argos monitoring stations are self-contained and may be left unattended for one year or more. Hourly seismic event summaries are transmitted from each monitored site every day. This helps to detect increased volcanic activity, prompting organization of further field campaigns or remote observation. Permanent monitoring can be offered without range limit, because the Argos system has worldwide coverage.

For two years, CLS / Argos has worked to offer a complete system, made of 1) two types of stations (seismic recorder and physical-chemical parameters), 2) the Argos data transmission link, 3) the dedicated software for data readout. This system, which has been extensively tested on Etna and Kelut volcanoes, can provide warning of increased volcanic activity at a low enough cost to permit instrumentation on many volcanoes.

This document gives more information about the global system for volcano observation, now available from CLS/Argos. There is also information on how both the Argos and the new Starsys LEO satellite systems work.

Volcano monitoring

Most aviation experts agree that volcanoes should be more widely monitored. Three jumbo jets experienced engine flameout and nearly crashed in the 1980's. But the significant eruptions in the 1980's were mostly on volcanoes with few previously-observed eruptions. This is why many experts are now calling for permanent systems on more volcanoes. Continuous volcano observation would provide a way of detecting early signs of activity. Monitoring more volcanoes would increase the probability of observing eruptions. It would help to protect aviation and civilian populations and to provide data for scientific studies.

When volcanologists study actively erupting volcanoes, they usually demand sophisticated observing stations, with high investment and maintenance costs. It is not feasible to establish permanent, sophisticated observatories on each volcano that poses a potential threat to aviation. Remotely monitored data collection platforms are a cost-effective alternative to large observatories. Argos-based platforms have many particularly attractive features: because they are reliable and drain little power, they can be left unattended for a year or more and transmit data several times per day. It is easy to protect and install the little equipment that is needed. In addition to geophysical parameters, they also transmit housekeeping data, i.e. their operational status and maintenance needs.

Data are relayed through low-earth orbit satellites for further processing. Increases in volcanic activity can be remotely monitored, and more intensive observations can then be made, initially using satellite images, and later, by installing additional instruments. This early detection system is of benefit to local populations, to scientists, and also to the aviation industry. The system is designed to be affordable in order to be installed on the vast majority of volcanoes that do not have manned observatories.

CLS Argos has worked with seismologists and volcanologists to define a basic volcano monitoring system. Some of these experts have now been using Argos data transmission for 10 years (INSU, French Institute for Sciences of the Universe). They have helped define the detection criteria for seismic events, as well as the short but significant data to be sent through Argos. The system includes field stations with Argos transmitters and dedicated software to access the data.

Stations

The stations we have developed have:

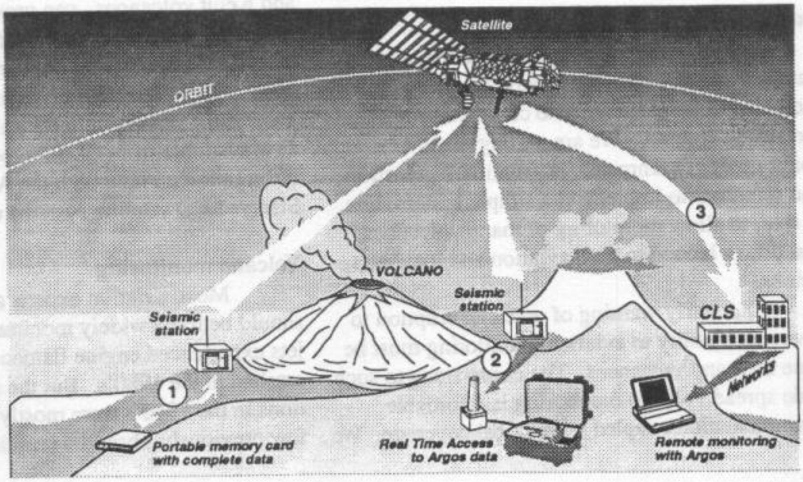
- high memory capacity so that data can be accessed on site,
- power supply by external batteries or solar panel,
- Argos transmitter for remote monitoring, with low power drain,

Three ways to access to data:

1- locally: full data set on removable memory card,

2- in line of sight and real time (several miles away from the platform), with radio receiver on Argos frequency,

3- with Argos satellite worldwide dissemination.



• transmission of housekeeping parameters.

The SISMO1 station is a stand-alone seismic station. The MONOA and the TAD 808 record slow-varying physical or chemical parameters using either off-the-shelf or custom-made sensors. SISMO1 is described in moderate detail. Further details on other hardware are available from the author.

Access to data

The system provides dual access to data locally, either by recovering the removable memory card (1), or by real-time, line-of-sight radio link using a receiver on the Argos frequency (2). All stations have programs for configuring the instruments and retrieving data. This can be done on site, using a portable PC, or in the observatory. Remote access to all your data is obtained from global and regional Argos processing centers (3). Data from a large number of stations can be read with a single program. The same platforms can be monitored from several places (even on different continents), by collaborative groups.

Advantages of the Argos transmission link

a) permanent access to data, in near-real time (results available in less than fifteen minutes when the platform is served by "regional processing" mode),

b) it tells that the station is working properly (housekeeping parameters),

c) it tells when critical events occur, so that imagery can be acquired,

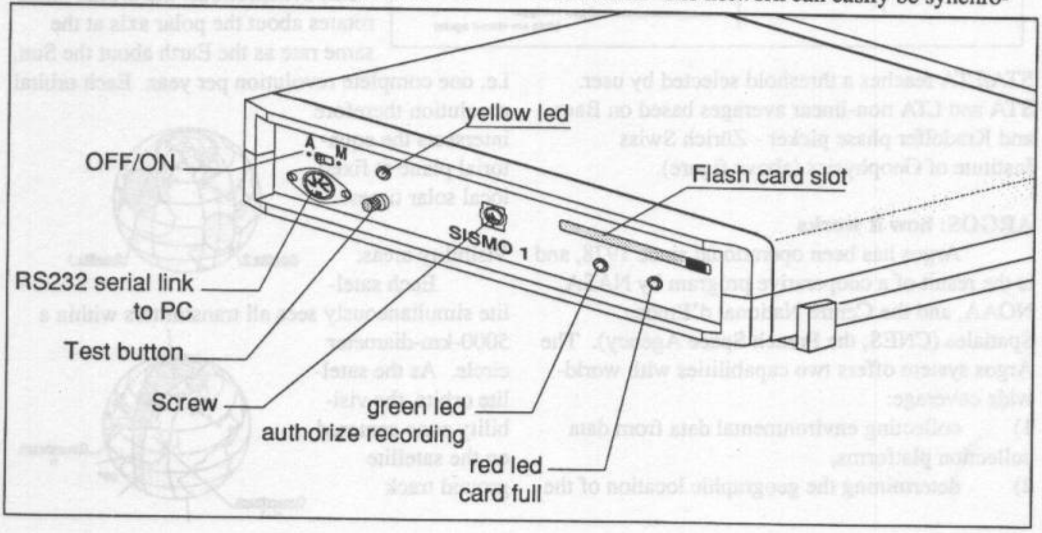
d) data are confidential but can be shared world-wide among authorized users.

SISMO1: the seismological platform

SISMO1 (shown below) is a portable datalogger that digitizes, processes and stores the ground velocity signal recorded by a geophone. It also transmits significant data via Argos. It is for two types of applications:

• long-term monitoring: one to three stations per volcano, with transmission of mean energy, number of seismic events relative to given thresholds, duration of tremors relative to given thresholds. The full data set is stored on credit-card size removable memory boards, with storage capacity of 1 to 4 megabytes.

• short-term comprehensive seismic studies: installation of a network for locating and tracking seismic events. The network can easily be synchro-



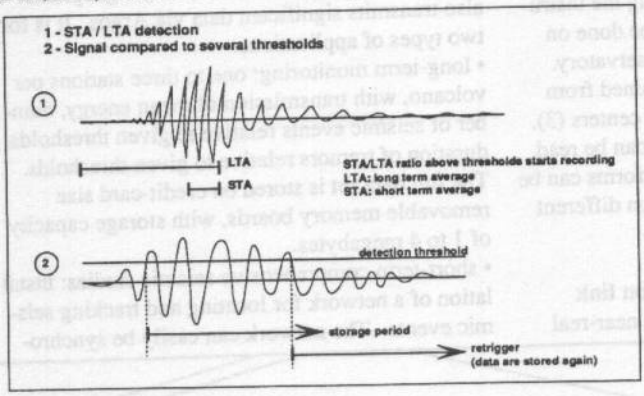
nized by Argos satellite accurate time-coding.

Event Detection

The signal is continuously digitized, stored in a ring-buffer, and compared to detection criterion. All criteria selected by user. Event and pre-event are stored in memory. Automatic gain is latched during event detection. Events are time tagged within 1/200 second.

There are three recording modes:

• continuous upon remote start-up
• continuous upon pre-defined time slots
• short term to long term average ratio criterion (STA/LTA): SISMO1 starts recording when



STA/LTA reaches a threshold selected by user. STA and LTA non-linear averages based on Baer and Kradolfer phase picker - Zürich Swiss Institute of Geophysics (above figure).

ARGOS: how it works

Argos has been operational since 1978, and is the result of a cooperative program by NASA, NOAA, and the Centre National d'Etudes Spatiales (CNES, the French Space Agency). The Argos system offers two capabilities with world-wide coverage:

1) collecting environmental data from data collection platforms,
2) determining the geographic location of the platforms.

The space segment

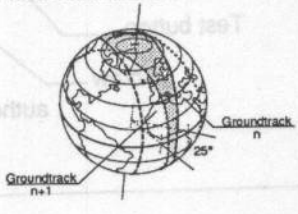
The first satellite was launched in 1978, and new satellites are launched every one or two years. The space segment comprises two NOAA satellites in simultaneous low earth orbit. They receive all transmissions from platforms in visibility during the entire orbital revolution. The signals are stored by tape recorders on board the satellite, and downloaded when the satellite passes above one of the ground stations. The onboard equipment also retransmits the data in real time. Presently, three satellites are in operation (NOAA-F, NOAA-H, NOAA-D), and one other is in backup.

The satellite orbits:

• Worldwide coverage with polar orbits
• Altitude: 830 km and 870 km for the two satellites.
• Period: approximately 101 minutes. That makes 14 orbital revolutions per satellite per day.
• Sun-synchronous: the orbital plane rotates about the polar axis at the same rate as the Earth about the Sun, i.e. one complete revolution per year. Each orbital revolution therefore intersects the equatorial plane at fixed local solar times.

Visibility areas:

Each satellite simultaneously sees all transmitters within a 5000-km-diameter circle. As the satellite orbits, the visibility zone centered on the satellite ground track



sweeps a 5000-km swath around the Earth that passes over the North and South poles.

As a result of the Earth's rotation, the ground tracks and swath shift 25° west (2800 km at the Equator) about the polar axis from one revolution to the next. There is therefore sidelap between successive swaths.

The Argos platform

An Argos platform is a data acquisition module (or datalogger), which sends data through a transmitter. Each platform transmits a short message (less than 0.92 s) by phase modulating a carrier frequency of 401.650 MHz. This frequency must remain very stable, because the location of mobile platforms is based on a Doppler effect calculation. Each platform repeats its message regularly, for example every 200 seconds. The message starts with an identification number, to make each platform unique. The message generally stays the same for a set period, to insure that it will be collected. Message length is selectable from 32 to 256 bits per message. Presently, over 4,000 Argos platforms are active world-wide.

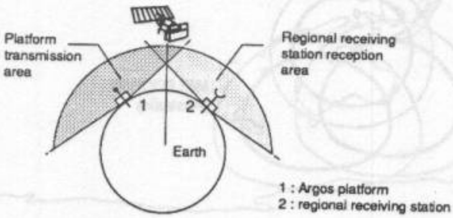
How data are relayed by the satellite

The Argos onboard equipment receives all messages transmitted by platforms within the satellite visibility area. Messages are received, processed and transmitted to ground in real time. They are also stored on an onboard recorder, and the full data set is retransmitted to each of the three ground stations: Lannion (France), Wallops (Virginia, USA), Fairbanks (Alaska, USA).

When data are available to users

Regional coverage:

The realtime downlink is for platforms close to receiving stations: the satellite sees the platform and the station simultaneously. In other words, the platform and station visibility circles overlap, and the satellite ground track crosses the overlap area. Data from platforms processed in regional mode are available to users more quickly. These platforms are also processed in Global coverage mode. Platforms within the heavy lines on the map are received in regional coverage mode.



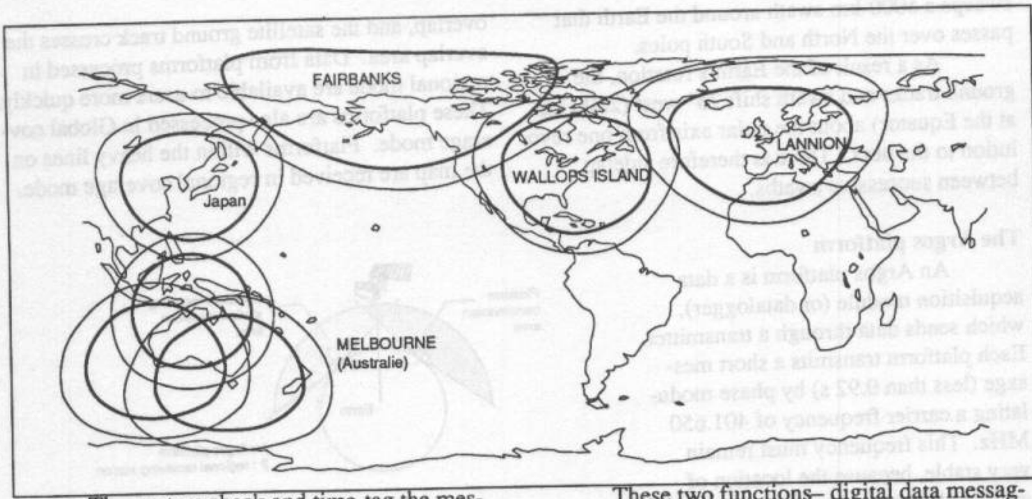
Global coverage:

When the platform is not in a regional coverage area, only recorded data are available. They are downloaded when the satellite passes above a ground station, then transmitted to one of the Argos processing centers.

Throughput time (delay from when message is received by satellite to when it is available to users) improves constantly. In global mode, 60% of messages are available in less than two hours. In regional mode, 60% of data are available in less than 15 minutes.

The Argos processing centers

The data received at the ground stations are relayed to two Argos data processing centers. These are designed for maximum availability and minimum data loss. One center is in Toulouse (France), the other in Landover (MD, USA). Centers in Tokyo and Melbourne have recently been opened, and provide regional coverage for platforms in the south-west Pacific. Each center operates around the clock, every day of the week. Each has three identical computers and thus offers internal redundancy: users' data can be processed even if only two computers are operating.



The centers check and time-tag the messages, and sort them by platform. On request, sensor data can be converted into physical values. Users access their results via an on-line dissemination system, supplying the last four days of data plus the current day. Data are also archived and can be recovered off line (tapes and floppies). Most users get their data via the Internet, but some connect to the centers through packet switched public networks (X25 protocol) or automatically receive updates by fax.

Introduction to Starsys

There is a need for two-way, rapid messaging of a sort that Argos is not designed to provide. To meet this need NACLS has joined Hughes-STX, to develop Starsys Global Positioning, Inc. The mission of Starsys is to develop a low Earth orbit (LEO) mobile satellite service (MSS) for providing low-cost, two-way, wireless transfer of data messages between mobile terminals and distant fixed-position ground stations. In addition to data messaging, the system will also be able to provide customers with accurate locations of their remote radio transmitters, thereby allowing tracking of mobile goods, vehicles, and individuals.

These two functions– digital data messaging and position determination, individually or combined– enable a wide variety of applications which are both useful and valuable for business, industry, government, and private use.

The low-cost design and operation of the Starsys system is expected to make Starsys services available and affordable to millions of users throughout the world. This low cost solution to a broad communications need will create strong demand for low Earth orbit mobile satellite service.

Starsys System Overview

Starsys Global Positioning, Inc., was formed to provide inexpensive, satellite data communications services for very large markets in a variety of applications. The system will transfer via satellite brief digital data messages between mobile radio transmitter/receivers (mobile user terminals) and distant ground stations. Through ground computer processing of radio signals, Starsys will also be able to determine the geographic location of transmitting mobile user terminals.

The company is an applicant to the United States Federal Communications Commission

(FCC) for a license to operate this system. License approval is anticipated early in 1994, with initial operations beginning within two years of licensing. Commercial operations will begin with two satellites in 1996, rapidly increasing to five to six satellites on orbit.

The development plan calls for twenty-four satellites to comprise the full constellation. The full constellation, with overlapping footprints, will provide near constant coverage, assuring that the mobile terminals are almost always able to contact, or to be contacted by, a ground station immediately.

Starsys system capabilities will:

- Let industry or government routinely check the environmental conditions of remote areas or sites; let utilities quickly gather remote meter data
- Allow security and status evaluations of remote sites and equipment
- Allow remote control of valves, switches, and other control mechanisms to regulate power and utility functions
- Allow individuals to send and receive personal and emergency messages
- Allow shippers or receivers to check the condition of goods in transit, or locate and track the movement of special interest cargos
- Enable quick position determination for recovery of lost or stolen vehicles
- Permit very low-cost two-way message traffic between fleet operators and mobile units at virtually any time at any location.

The very low cost Starsys global positioning and two-way data transfer system uses relatively simple low Earth orbiting satellites to relay digital data transmissions between distant communicating entities. Inexpensive, low-power, battery-operated remote radio receiver-transmitter units can originate data messages automatically, or can respond to "polling" by the ground station to originate a message.

These transceivers can allow Emergency Managers to: 1) receive early warning of changes in nominal levels of hazardous activities or events; 2) assess post-event status of infrastructure or ambient environmental conditions. The system can be entirely free of regional post-event conditions that can degrade ground-based communications systems.

Ground stations collocated in the satellite "footprint" with the transmitting unit send data to and receive it from the remote unit. All Starsys message traffic to and from remote terminals goes through the ground-based processing and analysis center which encodes the messages for spread-spectrum frequency transmission, and decodes the incoming signals for message routing.

Starsys progress

As part of its ongoing development process, Starsys has completed an initial satellite experimental program using S80/T, which was launched in August 1992. The experimental program was designed to test and validate the Starsys spread-spectrum transmission concept and verify operational capabilities in the allocated frequencies. Initial results have confirmed the viability of the spread-spectrum transmission mode, allowing further progress toward development of the system.

A full description of the Starsys concept is available from the author.

Conclusions

The need for regional or global networks for both early warning of disasters and rapid post-disaster assessments can be met now with data messaging through Argos, a low Earth orbit satellite system. Argos has a proven track record, with over 4,000 data collection platforms monitored world-wide today. A high-capacity, low-cost, two-way data messaging system, called Starsys, is under development, and will be available in 1996.

MMS: An Electronic Communication System For Emergency Management Organizations

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Abstract

The paper outlines the main features of an electronic communication system, MMS, designed as a dedicated coordination tool supporting Emergency Management efforts. The design of the MMS, which has been motivated by analysis of communication and coordination problems observed during EM actions, provides users with an overview of the follow-up history of any EM message and of unanswered requests and alarms.

Background

The MMS (Message Management System) is a system which is designed to support electronic communication of Emergency Management (EM) organisations. While a precursor of the system was initiated in a project led by Risø National Laboratory and sponsored by the European Community under the Esprit Programme (Esprit Project 2322 ISEM: Information Technological Support for Emergency Management; 1989-1992), the present version of the system, is the result of efforts mainly within a project of the Eureka Programme: MEMBrain (Decision Support Integration Platform for Major Emergency Management; 1993-98).

The system has been designed, first, as a general-purpose electronic mail system, and second, as an e-mail system with extended features especially dedicated for use by EM organisations and other types of organisations and companies operating in *safety critical domains*. In the following we describe some of the major features that distinguish MMS from most other e-mail systems as well as the motivation for their introduction. But we leave out features that can be expected to be present in any modern electronic mail system.

Decision makers involved in EM, including their aides and team leaders, have several needs in regard to support of communication and procedural information: Put in general terms, they need *timely and perspicuous* information. Thus, they need to have information about the status and development of "physical" events (past, current, and forecasted), about actions and procedures that are dictated, or perhaps suggested, by preparedness plans, about the status of current EM efforts and relevant EM resources, and about the reactions by the public and the press. While it is obviously important to provide information that helps to establish decision makers' awareness of the "objective" emergency situation, in the sense of the physical conditions that are endangering lives, environment and property, the importance of providing information about *the flow and status of EM-coordination* is sometimes overlooked. However, a communication system dedicated to supporting EM-efforts should, we believe, aid in conveying information about EM agents' intentions and plans, commands, acknowledgements of commands as well as their absence, and, in general, a picture of "who is doing what where and when".

It is this requirement - supporting the provision of an *overview of EM-coordination* - more than anything else which has prompted the design of the specific features of the MMS, in particular the division of messages into *types* such as REQUESTs and OKs and their linking and graphic 2D-display. However, before we sketch how these and other features work in the MMS, let us describe in slightly more detail some of the problems that motivated the design of the system.

Some problems concerning communication and procedural activities associated with EM efforts

Based on interviews with EM experts and surveys of reports of drills and real accidents or disasters, we have concluded that a number of problems seem to arise in connection with establishing an overview of how commands and requests are being followed up.

There are two sides to this. First there are the needs as they are defined from a sender's point of view, for instance, a busy decision maker and his aides who have dispatched a number of commands, requests, and alarm messages to a possibly large number of units need to know who has acknowledged and carried out the actions requested and who has not (yet). Conversely, if we define the needs from the receiver's point of view, we may think of a busy EM organisational unit, having received a possible large number of messages which have not yet been dealt with - in this case the unit needs to know what are the unacknowledged commands or requests to this unit waiting for them to react or respond to.

Besides the problem of keeping track of commands and responses to these, there are a number of other communication and coordination problems which to some extent can be lightened by proper systems support. But space does not permit us to go further into these matters in this paper. Here we merely give a list of such problems:

- A given sequence of messages from one organisational unit to another may be misunderstood by the receivers. This may happen when an initial message has not been opened or has been overlooked; then, when subsequent messages arrive that allude implicitly to the lost message, they are liable to be misinterpreted.
- A brief declarative message meant as a command by the sender can be interpreted mistakenly by the receiver as a piece of information.
- Decision makers and personnel at operating centres may become overwhelmed by "book-keeping" when they try to keep track of responses to their commands (requests) issued - i.e. commands not yet responded to, commands responded to but not yet completed and commands already completed.
- The meaning of a given message will sometimes be misunderstood if the message is not seen in the context of other messages to which it is related. The personnel of an operating centre who typically must deal with a great number of messages may lose track of the context of a given incoming message unless they are able quickly to tie it to the relevant preceding messages.
- Finally, while decision makers and their aides are usually familiar with the details of the relevant preparedness plans, there are often problems in communicating quickly alarms and requests to all relevant units as well as in determining if receivers have actually received, or acknowledged receipt of, such messages.

Specific MMS features

The following features have been implemented in the MMS design in order to overcome or alleviate problems in keeping track of coordination and communication:

- Initial messages are distinguished into REQUESTs and NOTEs. REQUESTs are messages that require a reply from receivers; NOTEs are all other initial messages.
- When receiving a REQUEST, a user will be prompted to send a reply. There are three types of replies he may send: an OK! message that contains no text; an ANSWER message that contains any free text composed by the user; and another REQUEST which then in turn will prompt its receiver for a reply.
- Message linking and classification into typed messages is based on the users' own classification of messages - the "smart" features of the system are governed by rules that operate entirely on message "envelope" properties most of which result from user inputs.
- Links among messages can be seen in a graphic tree display (see fig. 3) which also reveals different types of responses - providing, for instance, a quick view of who has failed to acknowledge a command or complete an action requested.
- A reminder function can be activated when sending an urgent REQUEST. The reminder alarm will alert the sender and/or the receiver after a given interval chosen by the sender depending on any of a range of criteria to be fixed by the sender.
- A set of status attributes is constantly updated for any message so that a sender, when looking at a list of messages, may see at a glance whether a message has arrived at the receiver's mailbox, whether it has been opened by the receiver, and, when applicable, what type of reply has been returned.
- A library of *structured messages* is supplied allowing users to fill out and submit standard reports with least possible effort.
- Integration between the MMS and the preparedness plan (PP) allowing users to keep an integrated overview of commands and acknowledgements and the status of current tasks as dictated by the PP.

Illustration of some MMS features

In fig. 1 is displayed the entry window of the e-mail system as it appears when the user has

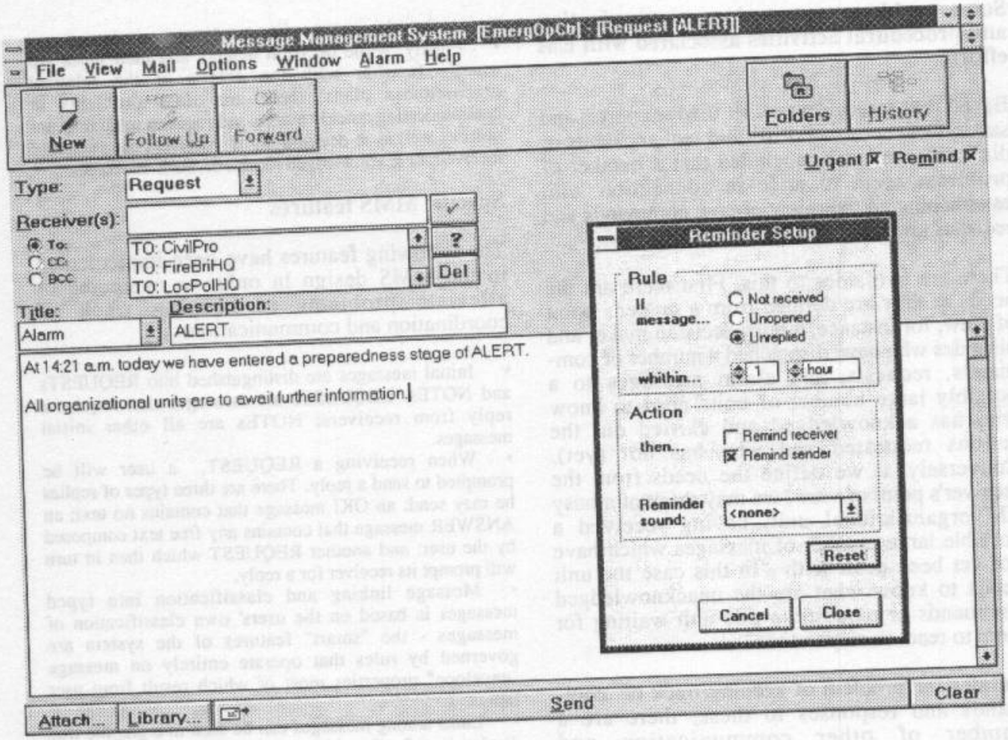

Figure 1

clicked on the *New* button - i.e., invoking the command "create new message".
The user has to mark the type as either a NOTE or REQUEST. While a NOTE is an ordinary message a REQUEST is a message that will prompt the receiver for a reply. So, a REQUEST is a message that the receiver is expected to respond to and possibly act on. We can also see in fig. 1 that in this particular case the user Emergency Operating Centre - has started his MMS application in an alarm situation that has been set in an accompanying module carrying a preparedness plan. The specific receivers may be picked as individuals or groups from a pre-written list of possible receivers. Furthermore, the reminder function (see fig. 1) may be invoked by the user allowing him to set a reminder alarm after a selected interval in case the receiver has not opened, or has not replied to the sender's REQUEST. The alarm can be set to notify either the sender or the receiver or both of them.

In replying to an initial message the receiver of this message may open a similar window for reply by clicking the 'follow-up' button. He will now be able to view the initial message while creating his reply. He is offered three types of replies: he can either send a no-text OK! message back, or he may send an ANSWER if he needs to add some text. Finally, he may choose to respond to the REQUEST he has received by another REQUEST - the latter option is to be chosen, of course, if he wants the sender to do something or if he just wants the sender to acknowledge his message. The reason why we have included a no-text OK! type of reply is, as explained above, that decision makers need to know precisely who among a possibly very large group of receivers has not reacted to a command.

In fig. 2 we are once again back at the original sender's screen, the Emergency Operating Centre. By using the alarm option, the user may for instance jump directly to the preparedness plan module (PP), or by setting the alarm mode and specifying the kind of alarm, he may fetch

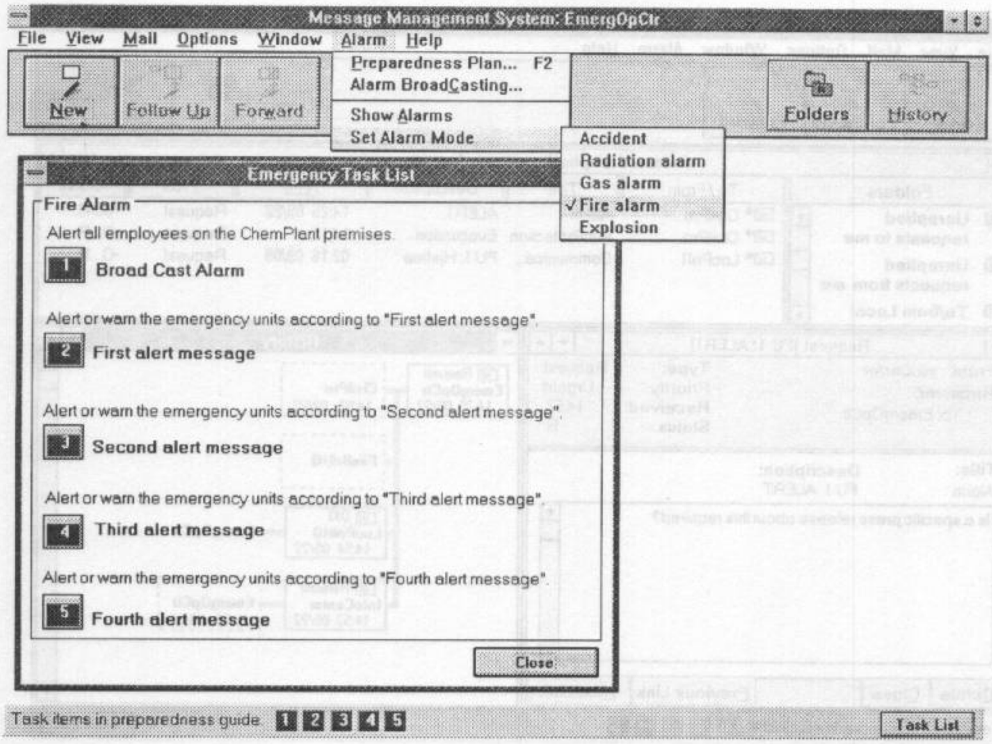

Figure 2

from the PP the specific list of actions to be carried out in the situation at hand. A task list, a generic version of which is shown in fig. 2, may either be a checklist for himself or it could be forwarded, if needed, to other participants or groups of participants in the emergency organisation.

In fig. 3 the scenario is continued and the sender has opened his folder *Unreplied requests from me*, finding in the folder his own original message sent out at 14:25. By clicking on the History button on the top tool bar, the user opens a tree-like display of the *history of the message*. The *History* function provides a picture that is automatically updated by the MMS displaying the flow of communication linked to the original message. By clicking on the boxes in the History diagram the user may make the selected messages apear in the bottom left cornor.The original message is symbolised by the box labelled "Request / EmergOpCtr / 14:25 09/22". The request has been sent to four receivers symbolised by four successor boxes. The top successor box, representing the receiver "CivilPro", is surrounded by a dotted line indicating that the receiver has not yet sent a reply; but it contains a time stamp that indicates that the receiver has opened the message at 14:57. The next box, denoting the receiver "FireBriHQ", is dotted and contains no time stamp, so our user can see that this receiver has not yet opened the original message. Then comes the receiver "LocPolHQ" who has replied by sending an OK! - this, recall, is the no-text reply option. To the right of LocPolHQ's box symbolising his OK! message the successor branch indicates to whom the OK! was sent (in this case this is superfluous information, in other cases it is not so.) Finally, the fourth receiver, the "InfoCenter", has sent a counter-request at 14:52 as is displayed here. Again, the dotted box to the right of InfoCenter's counter-REQUEST box symbolises that the receiver of this second REQUEST, EmergOpCtr, has opened the message at 15:00 and has not yet

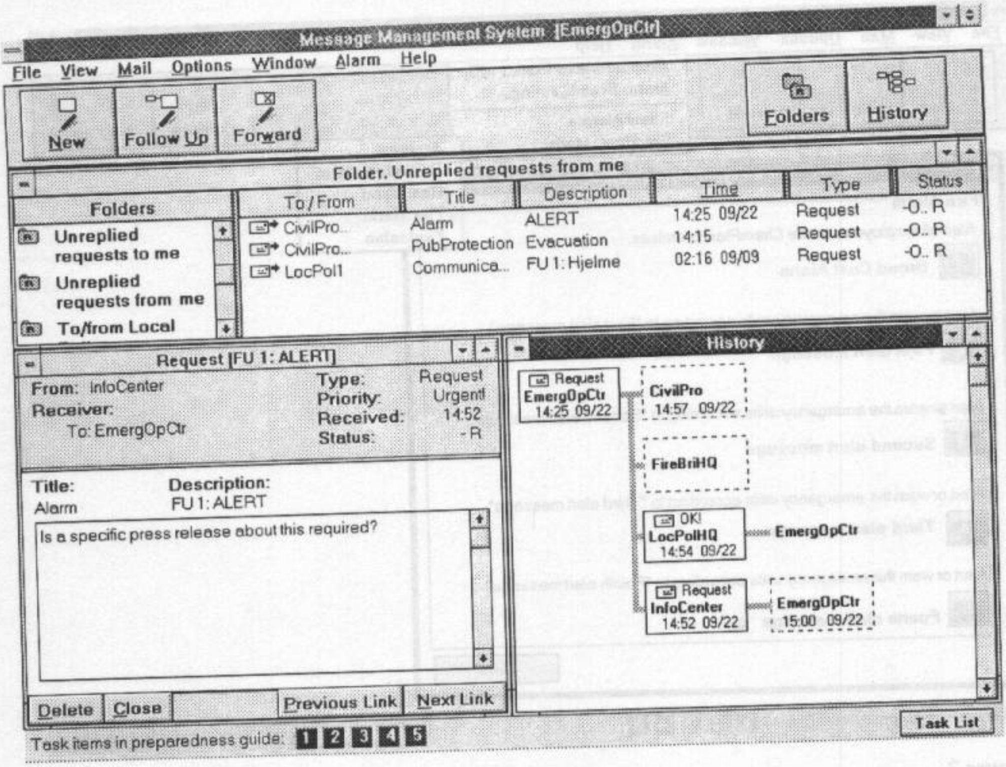

Figure 3

replied to it. Furthermore, it may be seen from this figure that after the task items have been identified, the checklist is maintained by the MMS and displayed at the bottom of all subsequent screens, indicating which tasks have been completed and which are yet to be carried out. At this stage, the five actions remain to be carried out, whereas in fig. 4 we can see that the 2nd action has been completed.

The MMS is supplied with a library of *structured messages*, each of which is configured in a "Structured Message Authoring Module". Fig. 4 gives an example of such a pre-written message form. This message form is, we imagine, a message that will be sent out by a certain chemical processing plant when an accident of a certain severity has occurred. The example chosen is the first alert message sent out. In this structured message form, every slot can be filled out automatically by the system on the basis of available data, including real time data provided from external modules. However, the slots with associated combo-boxes have to be filled out by the user. So, the *time* slot is filled out by the time stamp of the first alarm; the *date* comes from the machine clock. The *type of accident* is selected by the user from a list including an optional free text line. The *number of injured persons* is filled out by the user, and he may choose from a list, including an "unknown" option, or write free text. The slots indicating the *number of employees* and *guests* present are filled out by data from an automatic personnel recording system in use in several high-hazard industries or high security installations. Finally, a small weather station in use at the plant provides real time data for the *wind force* and the *wind direction* slots, while the user has to be the judge of the type of *precipitation* that prevails. In designing structured messages, great care has to be exercised in dividing the types of information

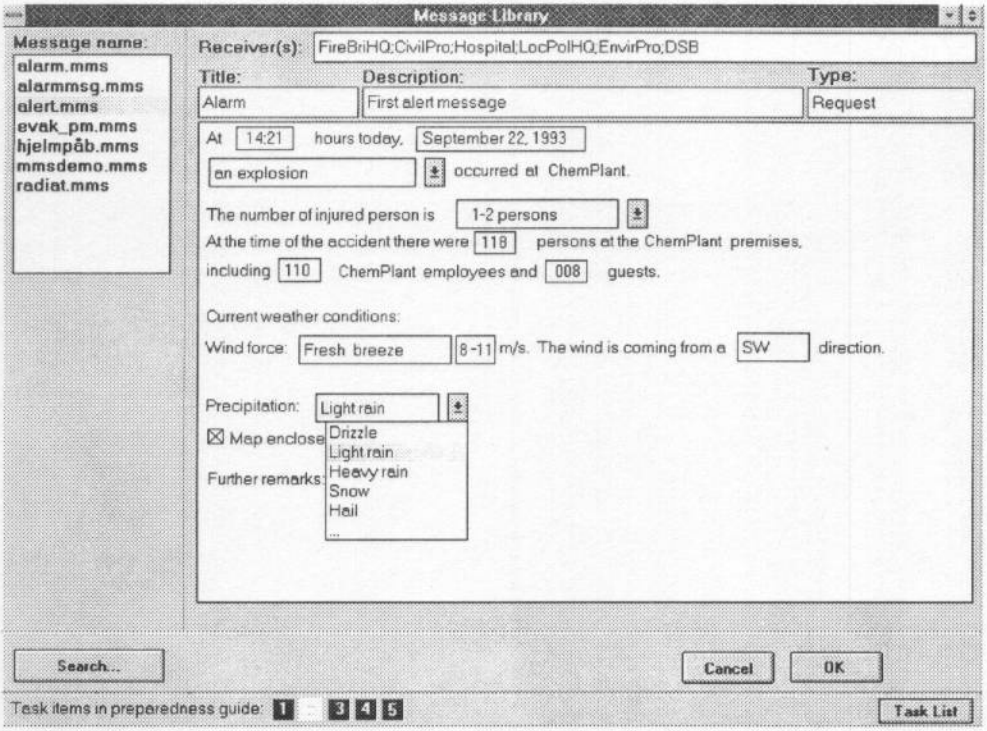

Figure 4

which sensibly and reliably can be supplied by machines and those which requires human operators to interpret and to exercise common sense.

Implementation details

The current version of MMS is a prototype that runs on top of Microsoft Mail and is implemented in Visual Basic. Current plans include implementing the MMS in an operational version for Windows NT, and porting it to the UNIX operating system. Ongoing efforts will extend the features that allow setting up structured messages and overview of work flow. Finally, as a consequence of requests expressed by field personnel, a simplified version of the MMS using *touch sensitive screens* will be implemented. The planned activities will be funded in part by Eureka project MEMBrain.

STATISTICS OF DISASTERS

COMPARATIVE STATISTICAL ANALYSES OF SOLID WASTE QUANTITIES AND STRUCTURAL DAMAGE BY HURRICANE ANDREW

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Abstract

The hurricane Andrew has generated approximately 2.4 million tons of demolition debris. An additional 0.5 million ton is estimated to be generated during rebuilding and repair of the buildings. The total of 2.9 million tons of structural debris is approximately equivalent to five years of landfill space. Extensive structural damage has been caused by the hurricane to roof coverings (tiles and shingles), mobile homes, wood framed walls and roof structures, large metal buildings, boats in marinas and trees. This paper presents the statistical analyses performed on the structural damage and structural waste quantities generated due to hurricane damage. The quantities of structural debris were analyzed for five areas with the most severe hurricane damage to the homes in Dade County, Florida, in relation to extent damage to buildings and amount of structural waste generated. The structural waste quantities were estimated based on the Hurricane Andrew Damage Assessment records compiled by the Metro-Dade County Building and Zoning Department.

1. Introduction

The hurricane Andrew has caused significant damages for roof coverings (tiles and shingles), mobile homes, wood framed walls and roof structures, large metal buildings, boats in marinas and trees. After the hurricane, approximately 135,000 residences needed either roof repairs or a complete overhaul. About 28,000 residences were declared uninhabitable. The damage to the buildings has created significant quantities of structural waste to be disposed of. The collection and disposal of solid waste after the hurricane incorporated limited separation of different types of materials

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such as wood, metals, household debris (rugs, furniture, electrical appliances, clothing), and construction and demolition debris. Most of the structural waste is unburnable and difficult to recycle due to contamination with different types of waste materials. During the cleanup activities after the hurricane Andrew, the solid waste collected contained over 50 percent structural waste (by volume). After the waste from trees were burned or chipped for recycling, structural waste fraction was over 80 percent of the total solid waste deposited in landfills.

2. Analyses of Damaged Areas

The damage data that was used in the analyses were compiled by Metro-Dade County Building and Zoning Department. Five zones with significant structural damage were selected in areas ranging in distance to the ocean and the hurricane eye landfall site. Figure 1 presents the locations of these areas.

Zone 1 is a recently developed area near the eastern Everglades, approximately 8 miles from the Atlantic coast. Concrete construction is the typical method with clay tile or shingle as the roofing material.

Zone 2 is the landfall site of the northern eye wall of the hurricane. The area is highly developed residential area with concrete construction and a wide variety of roof structures. There was also a slight storm surge of less than four feet in this area.

Zone 3 is also the coastal area containing Saga Bay and Gables by the Bay. The eye of the hurricane made landfall in this zone. There was a significant storm surge of less than 10 feet in this area. This zone is a new developed area with mostly wood frame construction with shingle roofs.

Zone 4 is approximately three miles inland from Biscayne Bay. It includes Homestead Air Force Base and part of the Homestead business district. This area is mostly agricultural with recently built small residential units. The structures are mostly wood frame with shingles and mobile homes.

Zone 5 is about 7 miles inland from Biscayne Bay. This area is mostly agricultural with a small business district. The structures are mostly wood frame with shingle roofs. This zone includes the Florida City and Redlands and borders the Everglades National Park.

Table I presents the characteristics of residences in each zone analyzed. Table II presents the number of residences and the number of homes damaged in each zone. Table III presents the corresponding quantity of structural waste requiring disposal in each Zone. The amount of structural waste for each zone was calculated based on the number of homes damaged and the composition of an average house in South Florida area. The average house was selected as a two bedroom house.

3. Conclusions

The amount of structural debris generated by the hurricane Andrew is significantly dependent on the land use. The quantitative and qualitative analyses and evaluation of the structural debris provide a good tool for future land use and development, emergency management planning, choice of building materials, planning of sequential clean-up and disposal activities and emergency solid waste management planning for coastal areas which could be hit by a hurricane such as hurricane Andrew.

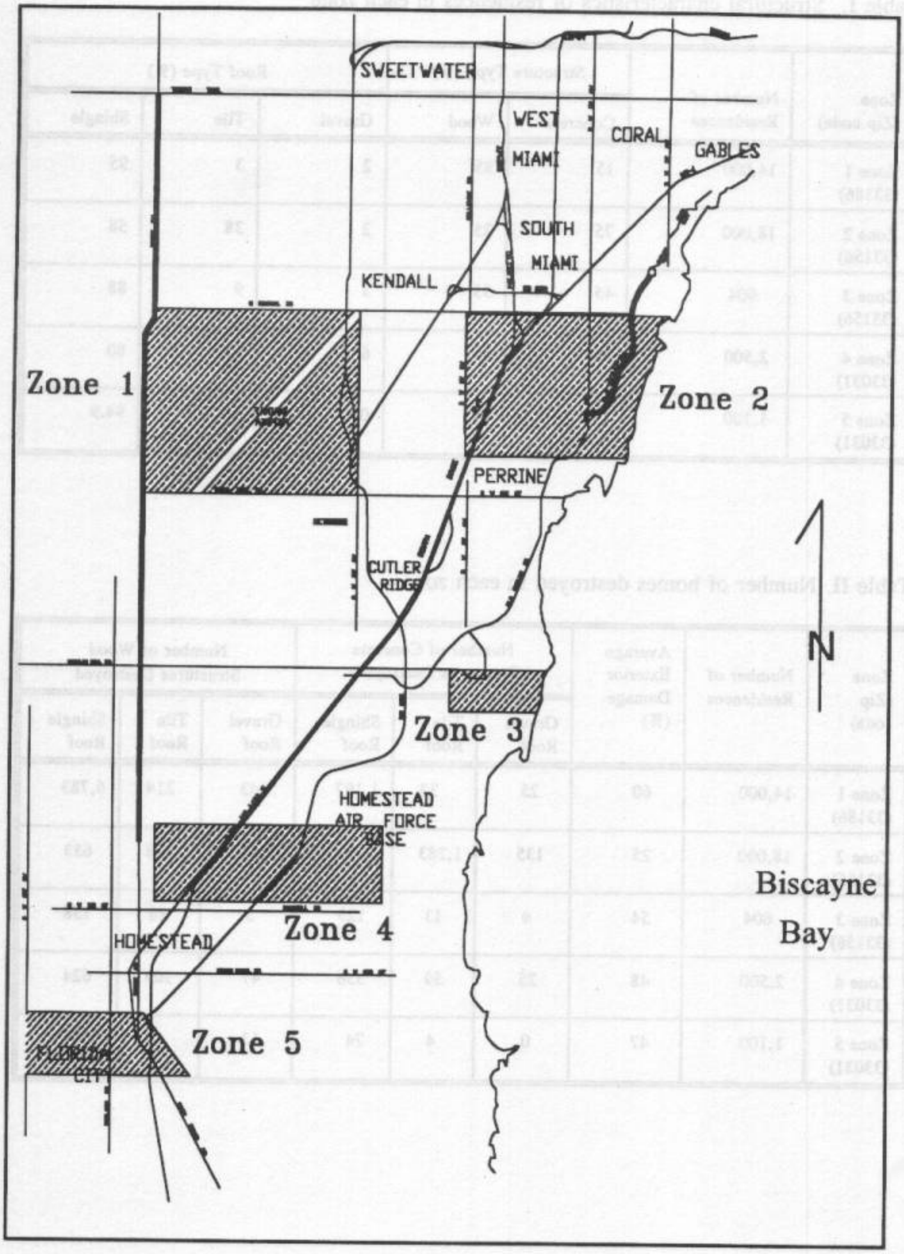

Figure 1. Locations of the five zones analyzed for structural waste generation.

Table I. Structural characteristics of residences in each zone

Zone (Zip code)	Number of Residences	Structure Type (%)		Roof Type (%)		
		Concrete	Wood	Gravel	Tile	Shingle
Zone 1 (33186)	14,000	15	85	2	3	95
Zone 2 (33156)	18,000	75	25	2	38	58
Zone 3 (33156)	604	45	55	3	9	88
Zone 4 (33031)	2,500	35	65	6	14	80
Zone 5 (33031)	1,100	15	85	0.1	5	94.9

Table II. Number of homes destroyed in each zone

Zone (Zip code)	Number of Residences	Average Exterior Damage (%)	Number of Concrete Structures Destroyed			Number of Wood Structures Destroyed		
			Gravel Roof	Tile Roof	Shingle Roof	Gravel Roof	Tile Roof	Shingle Roof
Zone 1 (33186)	14,000	60	25	38	1,197	143	214	6,783
Zone 2 (33156)	18,000	25	135	1,283	1,958	45	428	653
Zone 3 (33156)	604	54	4	13	129	5	16	158
Zone 4 (33031)	2,500	48	25	59	336	47	109	624
Zone 5 (33031)	1,100	47	0	4	74	13	40	387

Table III. Quantity of solid waste produced in each zone

Zone (Zip code)	Total Solid Waste Produced (Tons)	Solid Waste from Concrete Structures (Tons)			Solid Waste from Wood Structures (Tons)		
		Gravel Roof	Tile Roof	Shingle Roof	Gravel Roof	Tile Roof	Shingle Roof
Zone 1 (33186)	271,778	1,398	2,222	63,615	4,448	7,295	192,800
Zone 2 (33156)	221,417	7,492	75,385	104,031	1,402	14,560	18,547
Zone 3 (33156)	13,090	244	776	6,864	168	550	4,487
Zone 4 (33031)	45,625	1,398	3,456	17,857	1,458	3,719	17,737
Zone 5 (33031)	16,893	4	228	3,911	411	1,347	10,992

MAGNITUDE ANALYSIS USING BRADFORD DISASTER SCALE

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ABSTRACT

Disaster consequence magnitude analysis methods utilising the Bradford Disaster Scale (BDS) previously applied to fatalities and re-insurable costs is used to analyse evacuation data for both the UK and USA. Consistent fit to the data are obtained using both exponential and Weibull probability density functions (pdf). Return periods as a function of the number of population evacuated are calculated for both the UK and USA. Examination of the (pdf) parameters estimated values of the (pdf) parameters obtained by using Maximum Likelihood suggest that even allowing for uncertainty associated with sample size, on balance significantly more people are evacuated in an emergency in the USA than in the UK.

INTRODUCTION

In order to compare disasters arising from different sources it is useful to use quantitative measures. For this purpose Keller (1) introduced the Bradford Disaster Scale (BDS) which is based on the logarithm of the number of fatalities involved in the occurrence of a disaster. It has been shown that the method is useful for disaster analysis, hazard identification and quantification; it can also be used as a tool for structured and strategic planning.

Whilst death is the most significant and most easily identified consequence associated with disaster, other consequences such as injuries, cost of damage, evacuation, social disruption, psychological trauma and environmental impact cannot be neglected. Evacuation and temporary housing of evacuees is obviously an important element in emergency planning. Due to the complexity of these consequences, a comprehensive quantitative measure to satisfy all planning needs is difficult to formulate.

The approach developed in this paper and elsewhere Keller et al (2,4); Keller et al (5) is to consider consequences existing in a multidimensional manifold and to formulate scales for each of these dimensions. Consequences of disasters can then be considered as a vector whose components are given by individual scale values for each dimension.

In accordance with this philosophy, somewhat simplistically, an initial two-dimensional consequence space was assumed Keller and Al-Madhari (7). The scales adopted for these dimensions were fatalities and re-insurable costs of disaster.

In the present paper, a third dimensional consequence is added to the above two-dimensional consequences in order to cover evacuation. The present paper also demonstrates how techniques developed for obtaining return periods for the earlier two-dimensional consequences, fatality and cost magnitudes, can be applied also to evacuation.

In order to avoid unduly large and difficult to handle data sets, a disaster is now defined as:

"An event localised both in time and space if one or more of the following consequences occur
1). 10 or more fatalities
2). damage cost exceeds US $1 million
3). 50 or more people evacuated."

This definition is an extension of the definition of disaster given by Keller and Al-Madhari (7) which is expressed in terms of fatalities and re-insurable damage costs only. The threshold values of 10 fatalities, US $1 M and 50 evacuated persons are pragmatic and not absolute and are chosen for convenience of producing clean and manageable data sets. For example, Keller et al (3); Keller et al (6) in an analysis of disasters in the oil and chemical industries, because of the relatively small number of disasters having detailed documentation, used a fatality threshold of 5. Similarly, in Keller et al (2,4), in dealing with disasters of a global nature, because of the very large number of disasters involved and the possible under-reporting of "small" disasters, a fatality threshold of 20 was assumed.

In earlier papers (2,4,6,7), a probabilistic model is developed in which inputs for the model are frequency of occurrence and magnitudes of disasters of the particular type being studied. Expressions derived from the model include the return period for disasters having magnitude equal or greater than a particular value. This method has been applied by Keller et al (2,4) to disasters of general nature that have occurred in the geographical areas of the USA, Europe and the UK. In a more structured application the method has also been applied by Keller et al (6) to the disasters referred to above which have occurred during the period 1970-1987 within chemical and allied industries. Again this method also has been applied by Keller and Al-Madhari (7) to earthquakes, floods and climatic disasters. As described in (2,4,7) the method has since been extended to allow for analysis of re-insurable losses for disasters in both the USA and Europe and for earthquakes, floods and climatic disasters world-wide.

In the present paper the methods previously developed are applied to evacuation consequences resulting from technological disasters in the UK and USA. Data covering the years 1970-1993 were obtained from the MHIDAS database of the British Health Safety Executive (HSE).

FATALITY SCALE

On the Bradford Disaster Scale magnitude is defined by taking the common logarithm (base 10) of the number of fatalities resulting in a disaster.

A similar form of scaling based on common logarithms had been previously used by Richardson (8); further reference to this scaling technique can also be found in Marshall (9).

Supplementary to magnitude scaling a classification system, Keller (1), was introduced for analysis of large data sets where fatality data values are not necessarily precise.

COST SCALE

In a similar way to the fatality scale a cost scale can be defined where the magnitude of the cost component is the common logarithm of the re-insurable losses in US $ M

EVACUATION SCALE

In a similar way to the fatality and cost scales an evacuation scale can be defined by taking the common logarithm of the number of people evacuated as a result of the event.

DISASTER CONSEQUENCES MODELS

Fatality

It has been found that for a large number of magnitude consequence data sets analysed, an exponential distribution gives a good fit Keller et al (2,4,6); Keller and Al-Madhari (7); an example of the use of the exponential distribution indicating the degree of fit is given in Figure (1) for the case of general UK disasters which occurred during the period 1960-1990.

Re-insurable Cost

For re-insurable cost modelling, it has been previously found that the two-parameter Weibull distribution provides a good fit Keller et al (2,4); Keller and Al-Madhari (7); an example of this is given in Figure (2) for re-insurable costs of general USA disasters.

Numbers Evacuated

Using the MHIDAS database two data sets of technological disasters were compiled for the period 1970-1993 for the UK and the USA. A threshold of 50 evacuees was assumed. These data sets were analysed using both the exponential and Weibull distributions. Indications of goodness-of-fit to the data for both the exponential and Weibull distributions are given in Figures (3-6). Values of parameters of these distributions derived using Maximum Likelihood are given in Table (1). Also included in Table (1) are annual occurrence rate and normalised occurrence rate for the UK and the USA assuming a normalised population of 10^8 for both countries. This has been done in order to be able to provide direct comparison between the UK and USA.

Table (1). UK and USA Technological Disasters Evacuation Distribution Parameters

Parameters / Location	UK	USA
Annual Rate λ_e	4.5	15.7
Normalised per 10^8 Population λ_n	7.8	6.3
Exponential Parameter β	1.39	0.87
Weibull Shape Parameters η	0.93	1.31
Weibull Scale Parameter τ	0.70	1.21

CALCULATION OF RETURN PERIODS

Fatality

Values of return periods for disaster of magnitude greater than m were calculated using the formula

$$t_R = \frac{1}{\lambda R(m)} \qquad (1)$$

where

$$R(m - m_o) = \begin{cases} \beta e^{-\beta(m-m_o)} & \text{if } m \geq m_o \\ 0 & \text{if } m < m_o \end{cases} \qquad (2)$$

and λ is the annual occurrence rate of disasters classified by fatalities.

Re-insurable Cost

Values of return periods for disasters of magnitude greater than m_c is given by

$$t_R = \frac{1}{\lambda_c R(m_c)} \qquad (3)$$

where

$$R(m_c) = \begin{cases} e^{-(\frac{m_c}{\tau})^\eta} & \text{if } m_c \geq 0 \\ 1 & \text{if } m_c < 0 \end{cases} \qquad (4)$$

and λ_c is annual rate of occurrence of disasters classified by re-insurable cost. Derivations of (1) and (3) are given in Keller et al (2,6).

Evacuation

Return periods for numbers evacuated can be calculated in a manner similar to that used for fatalities and re-insurable costs.

DISCUSSION OF RESULTS AND CONCLUSIONS

Values of the parameters β, η and τ for Figures (3-6) are given in Table (1). It can be noted from formulae (2) and (4) that for the special case of the shape parameter $\eta=1$, the Weibull distribution degenerates to the exponential which mathematically is particularly convenient to manipulate.

Table (1) indicates that preliminary adoption of an exponential distribution, until further analyses have been carried out, to describe numbers evacuated is not an unreasonable procedure; this is confirmed in Figures (3-6).

Return periods for numbers evacuated assuming an exponential distribution for the UK and USA is given in Figure (7). For comparison purposes corresponding normalised return periods using λ_n are given in Figure (8).

It is seen that taking population size into account the normalised occurrence rate for the UK and USA are directly comparable. This indicates that the two data sets used are not inconsistent.

The difference in values of β for the UK and USA appear to be greater than one would expect from sampling error and suggests a possible real difference in emergency evacuation procedures in the UK and USA with possibly up to twice as many people being evacuated on average in the USA.

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Figure (1). Fatalities UK Disasters (1960-1990)

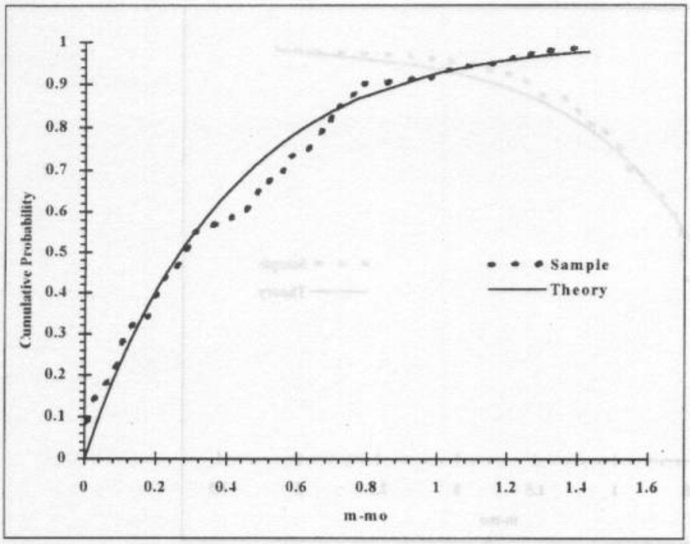


Figure (2). Re-insurable Costs USA Disasters (1982-1991)

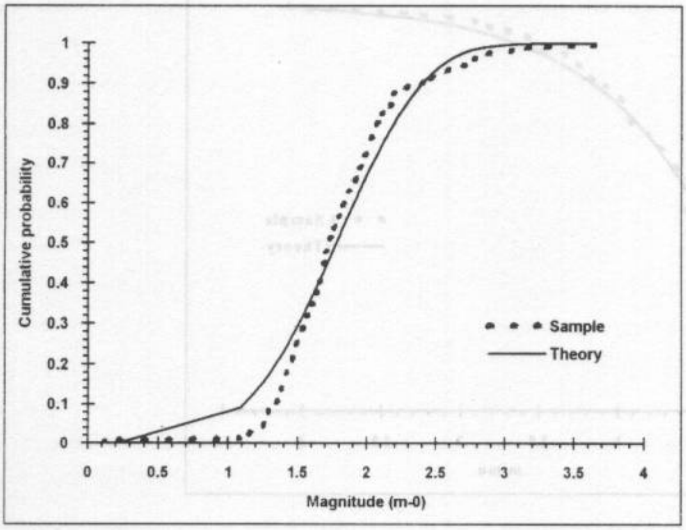


Figure (3). Evacuations UK (Weibull Plot) 1970-1993

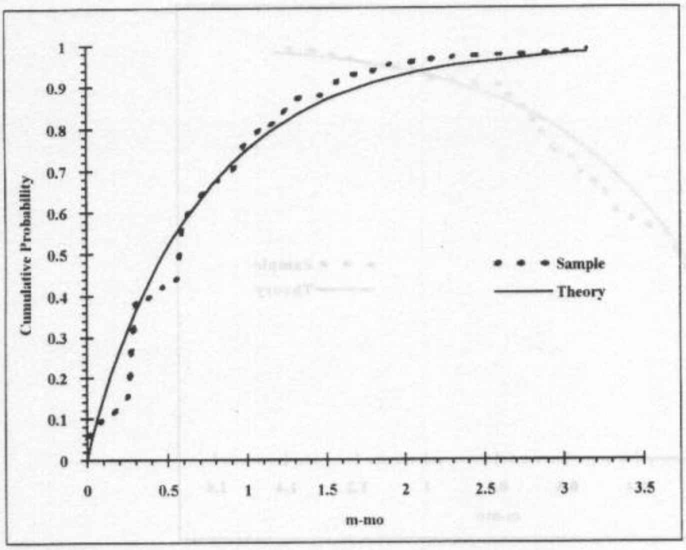


Figure (4). Evacuations UK (Exponential Plot) 1970-1993

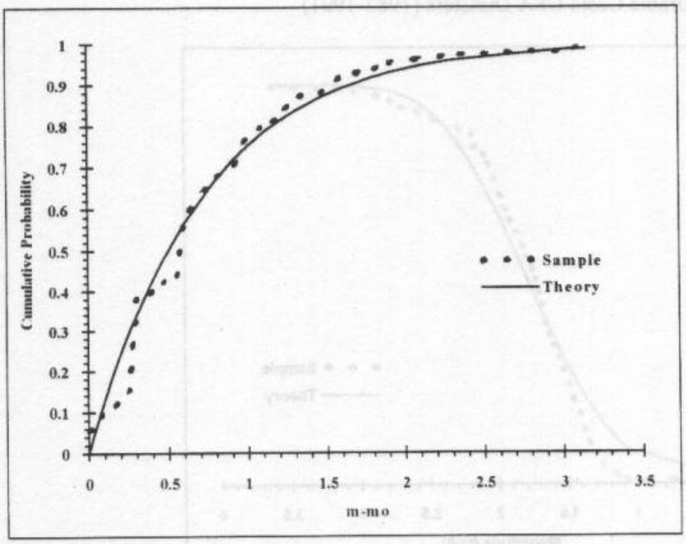


Figure (5). Evacuations USA (Weibull Plot) 1970-1993

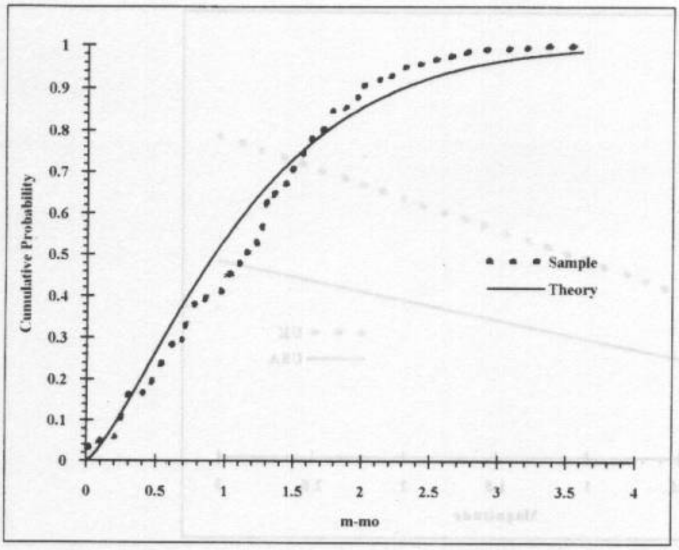


Figure (6). Evacuations USA (Exponential Plot) 1970-1993

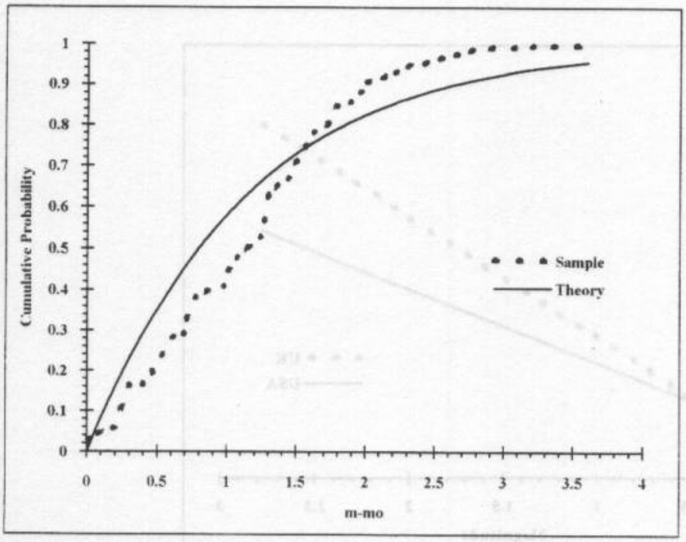


Figure (7). Evacuations Return Periods UK and USA

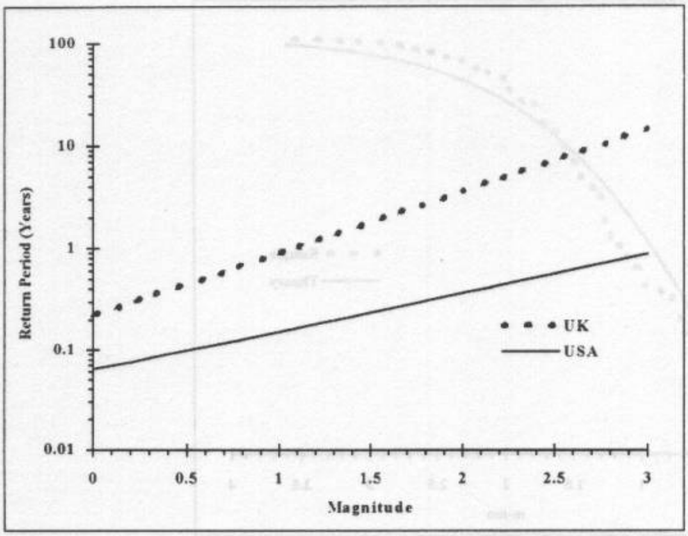
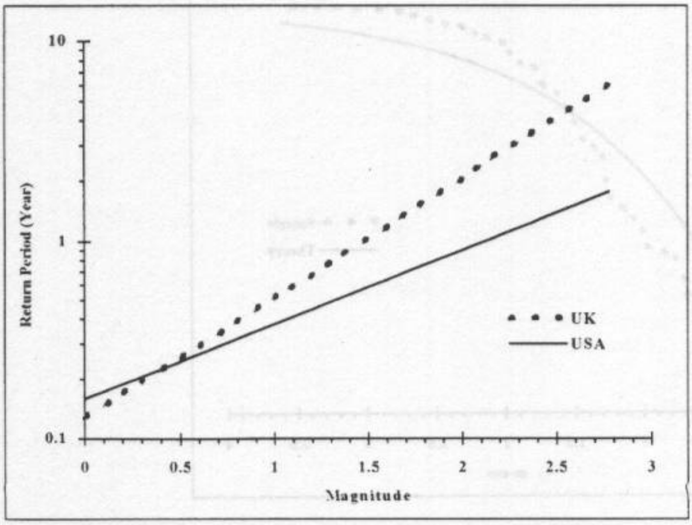


Figure (8). Evacuations Normalised Return Periods UK and USA



DISASTER STATISTICS: REVISITING THE FIRE PROBLEM IN THE UNITED STATES

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ABSTRACT

This paper revisits an earlier study on fire statistics in the United States. Additional data have recently become available, and some important changes in trends are noteworthy. Specifically, monetary and human costs over the period 1980 through 1991 are examined.

INTRODUCTION

John R. Hall, Jr., has provided an annual report on the total cost of fires in the United States for many years (Hall 1993). A cost/benefit analysis was carried out by the author two years ago (Sullivan 1992), and it is time for a follow-up to that report.

Hall breaks the total cost of fires in the United States down into several categories. One way to describe the two major categories Hall uses is economic and non-economic. Economic costs are those losses sustained directly or indirectly in a fire. Non-economic costs are those for fire protection. The terminology is perhaps not ideal, but consistent with prior use (Hall 1991 and Sullivan 1992). Clearly, one would hope that increased fire protection expenditures (over and above inflation) would proportionately reduce the economic losses from fires.

Economic costs may be further broken down into three components: reported, unreported, and indirect. Reported and unreported costs are direct expenses, whereas indirect losses refer primarily to business interruption costs.

In this paper, all monetary values discussed have been adjusted (for inflation) to 1991 dollars, using the Consumer Price Index. Values can be found on page 481 of "Statistical Abstracts of the United States", 113th edition, for the years under consideration (1980 through 1991).

ECONOMIC LOSSES

Figure 1 displays reported direct costs of fires. The data are somewhat erratic, but a general declining trend is apparent. In this and subsequent graphs, linear least-squares curve fitting has been used. Both the actual data (adjusted for inflation) and the least-squares fit show about a billion dollar decrease over the years under consideration. This amounts to about a ten percent reduction.

Figure 2 graphs the unreported direct costs of United States fires. The actual data are very erratic, but a small decrease over time is evident.

Figure 3 charts the indirect costs of fires. The data are erratic, but a significant decrease over time (20 to 30 percent) is evident.

Figure 4 shows the total economic losses of fires in the United States. Once again, the data are erratic, but a declining trend (slightly over 10 percent) is apparent.

So, it is fair to say that a general decline occurred over the period from 1980 through 1991. However, the decline can be characterized as "modest".

NON-ECONOMIC COSTS

Perhaps "fire protection costs" is a more descriptive term than "non-economic costs", but we will use the latter terminology to maintain consistency with earlier work (Hall 1991 and Sullivan 1992). What we are interested in here is the costs which are involved in waging war against fires. This category of expenses can be broken down into career fire department costs, building construction costs, and net insurance costs.

Career fire department costs are those associated with running fire departments: salaries, equipment, etc. Figure 5 demonstrates how much has been spent over the last few years in this area. The data are fairly linear, with roughly a 50 percent increase over time. This is a disturbing trend, since this is almost five times what the decrease in total economic cost is. The trend has leveled off over the last few years, and we can only hope this abatement continues.

Building construction costs are those associated with fire protection (sprinklers, smoke alarms, etc.). The least-squares fit has about a 30 percent increase, whereas the actual data increase at about 15 percent. Again, this category of expenses is increasing faster than the economic cost of fires is decreasing.

Net insurance is the amount left over after insurance companies pay out their claims. Figure 7 displays these costs from 1980 through 1991. There appears to have been about a 50 percent decline in these costs over this time span. This might seem to be good news, but it definitely is not: if this trend continues, it will only be a few more years before either insurance companies go out of business or have to raise their rates dramatically. Insurance companies refer to net insurance costs by different terminology: operating expenses and profits. Although some of this decline may be due to automation and other productivity enhancements, there is little doubt that most of the decline is due to premiums not keeping pace with claims.

Since net insurance costs are being driven by different forces than either career fire department or building construction costs, summing these three quantities is somewhat deceptive. However, such a total does give us a measure of our monetary outlays for fire protection. The actual data (see Figure 8) show about a ten percent increase from 1980 through 1991. The least-squares fit estimates an increase of over 20 percent. So, at best we are doing about the same as in 1980, and at worst, we are doing about ten percent worse than we were in 1980.

Another method of demonstrating this is to compare the economic costs of U.S. fires with the total cost (economic plus non-economic) of fires. Since we obtain unitless ratios, the effects of inflation are eliminated. This method also shows the trend to be generally increasing. (Graph is at end of text.)

HUMAN COSTS

Another dimension of the United States fire problem is the costs to humans in terms of lives lost and injuries. Hall considers both civilians and fire fighters in his data.

Figure 9 graphs the civilian deaths due to U.S. fires. Significant progress seems to have been made, especially during the last few years. The actual data have about a 30 percent decrease, whereas the least-squares fit shows about a 20 percent decrease. This is good news, and we can only hope this trend continues.

Figure 10 charts the fire fighter deaths. Again, important progress has been accomplished. The actual data show about a 20 percent decrease, and the least-squares fit displays an approximate 15 percent decrease. This is more good news.

Figure 11 shows the number of injuries to civilians from 1980-1991. There is a small decrease in evidence here. The least-squares fit declines about 6 percent over the twelve-year period, but the actual data decrease only about 3 percent. In absolute numbers, this is not good news when compared to the increase in non-economic costs.

Figure 12 displays the number of injuries to fire fighters. Note that although the ratio of civilian deaths to fire fighter deaths is about 40 or 50 to 1, the ratio of injuries for fire fighters to civilians is about 3 or 4 to 1. These ratios have been roughly constant over the years surveyed here. Unfortunately, the number of injuries to fire fighters has increased slightly over this time span: the actual data show about a 5 percent increase, but the least-squares fit has less than a 2 percent increase. Again, this news is not good.

If these injury and death data were adjusted for population, the results would be only slightly more positive since the population increased by about 10 percent over this period of time. (See, for example, page 360 of the "World Almanac", 1994).

CONCLUSION

In monetary terms, there is still a serious problem with fires in the United States. We are spending more and getting less for it, at least in terms of the economic cost of fires. Over the last few years, however, these trends appear to be changing in a positive direction. There is still a major problem with insuring against fire risks, and one that may soon cause turmoil in the insurance industry.

Progress in reducing human costs of fires is very encouraging overall. It will be very interesting to see if these trends continue.

Computer, communications, and other advanced technology have been receiving widespread acceptance in the fire fighting community over the last few years. Although it would be difficult to prove, that may well be the cause of the improvements observed in these statistics.

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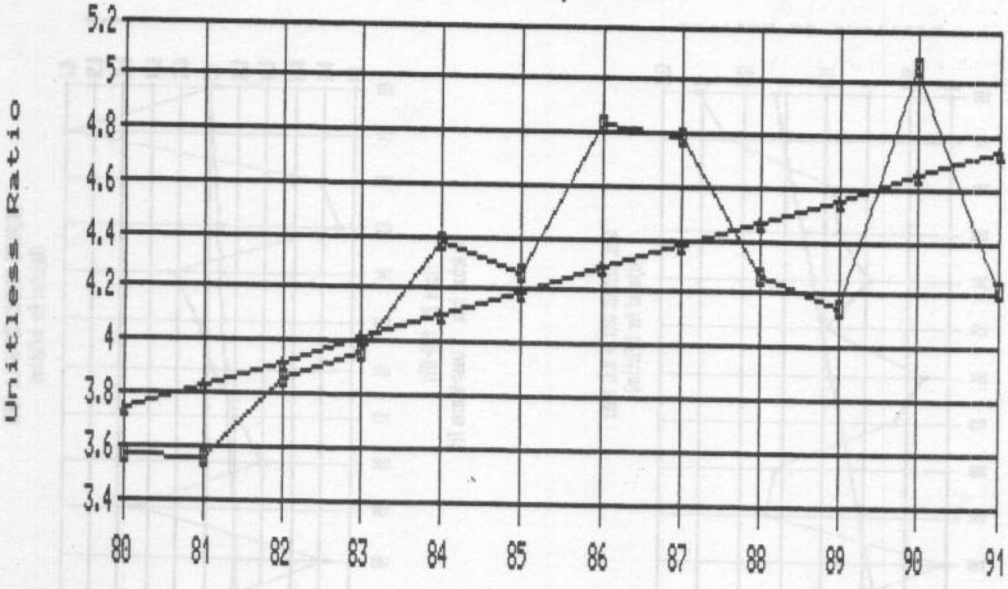
BIOGRAPHICAL SKETCH

James D. (Jim) Sullivan has served as a leading organizer for five international emergency management and engineering conferences. He is the founder and current president of The International Emergency Management and Engineering Society. Mr. Sullivan has published over a dozen papers on the use of advanced technology in emergency management, as well as a variety of papers on other subjects.

He has been an independent consultant since 1983. Mr. Sullivan had several years of experience as a programmer, programmer/analyst, and senior systems analyst prior to becoming a consultant. He holds the designations of CCP, CDP, and CSP from the Institute for Certification of Computer Professionals (ICCP). Mr. Sullivan specializes in training, assistance in hardware/software selection and acquisition, and systems development.

RATIO OF TOTAL COSTS TO ECONOMIC COSTS
Alternate Data Analysis Method



Years: 1980-1991

□ Actual Data ▵ Least-Squares Fit

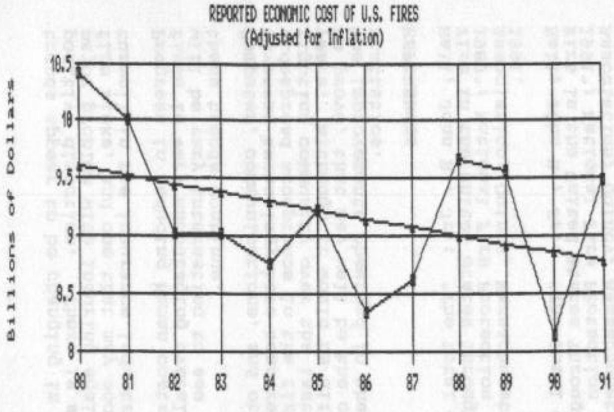


Figure 1: 1980-1991
▫ Actual Data ▵ Least-Squares Fit

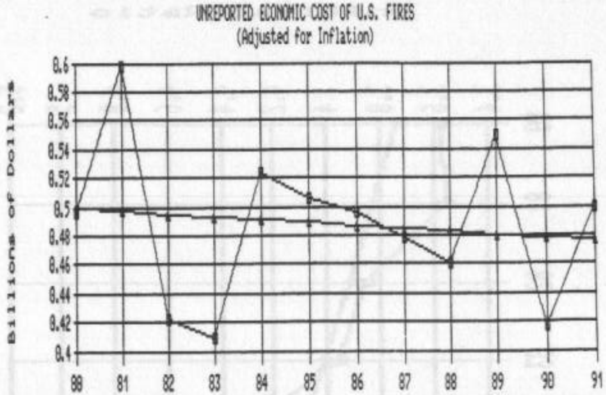


Figure 2: 1980-1991
▫ Actual Data ▵ Least-Squares Fit

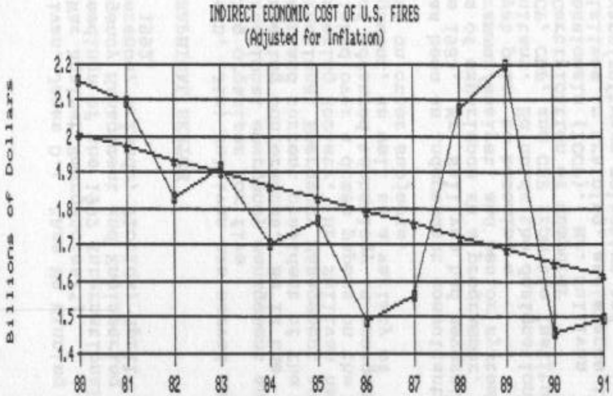


Figure 3: 1980-1991
▫ Actual Data ▵ Least-Squares Fit

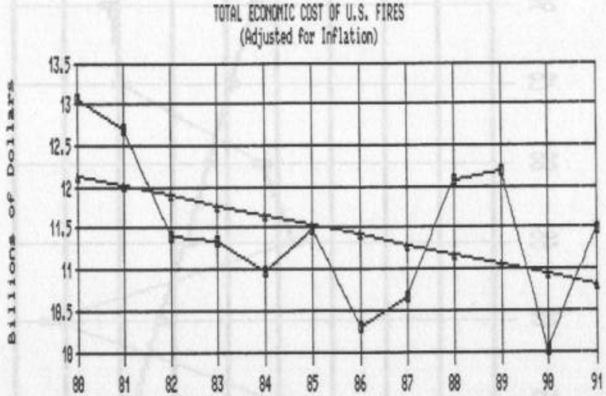


Figure 4: 1980-1991
▫ Actual Data ▵ Least-Squares Fit

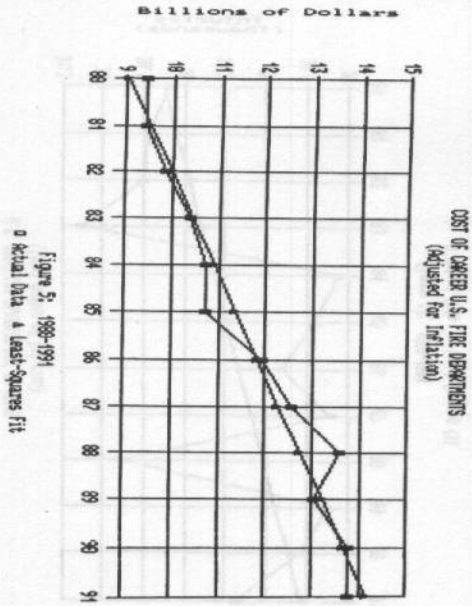


Figure 5: 1980-1991
□ Actual Data △ Least-Squares Fit

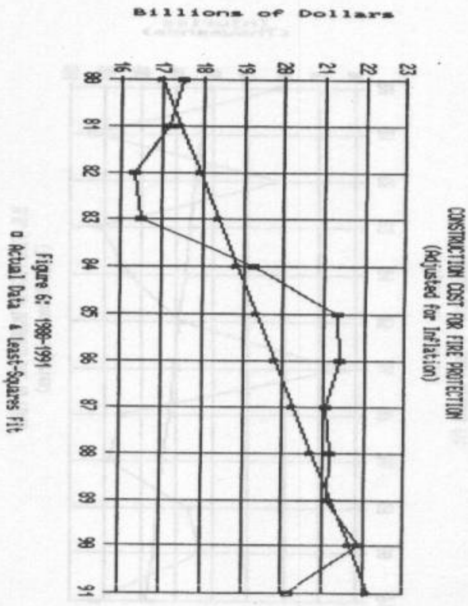


Figure 6: 1980-1991
□ Actual Data △ Least-Squares Fit

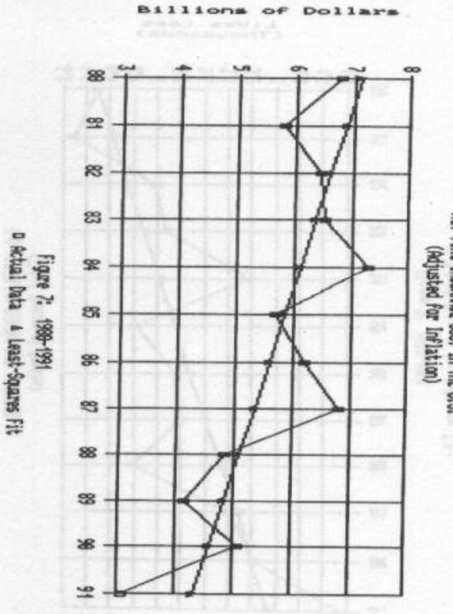


Figure 7: 1980-1991
□ Actual Data △ Least-Squares Fit

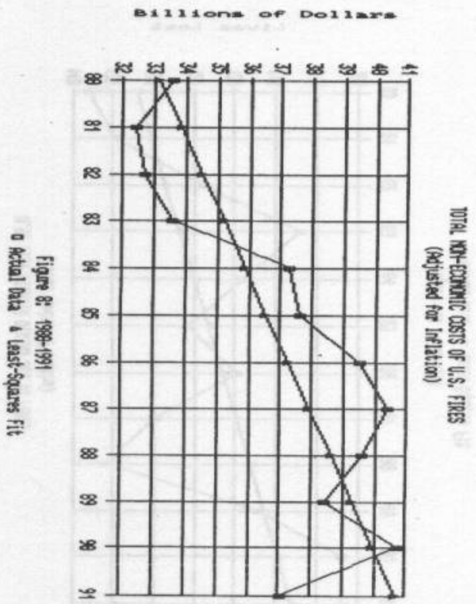


Figure 8: 1980-1991
□ Actual Data △ Least-Squares Fit

U.S. CIVILIAN DEATHS DUE TO FIRES
(Total Number of Deaths)

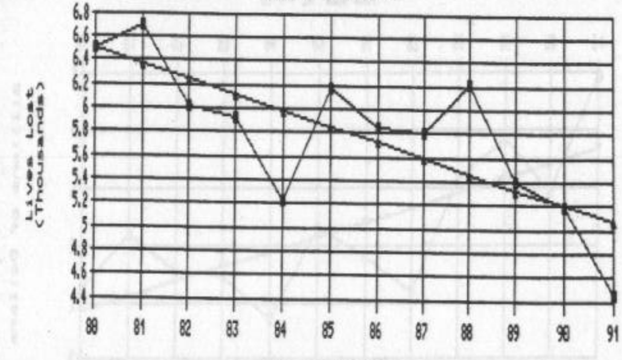


Figure 9: 1980-1991
□ Actual Data ▲ Least-Squares Fit

U.S. FIRE FIGHTER DEATHS DUE TO FIRES
(Total Number of Deaths)

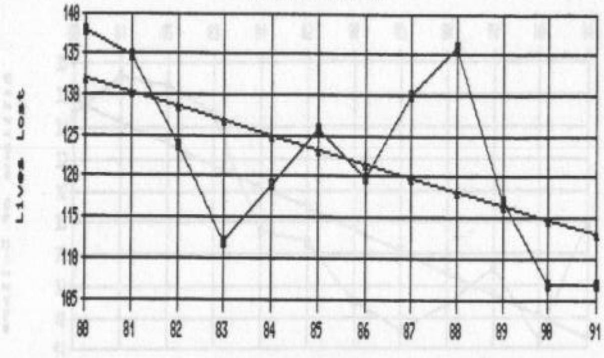


Figure 10: 1980-1991
□ Actual Data ▲ Least-Squares Fit

U.S. CIVILIAN INJURIES DUE TO FIRES
(Total Number of Injuries)

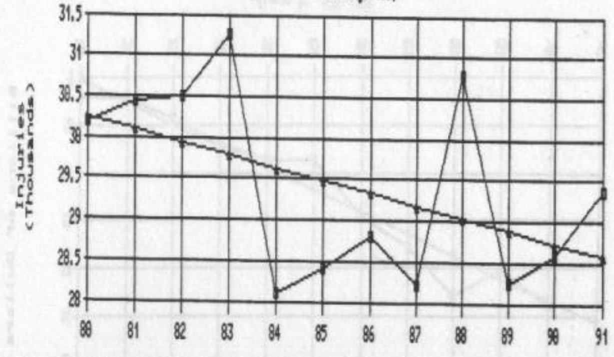


Figure 11: 1980-1991
□ Actual Data ▲ Least-Squares Fit

U.S. FIRE FIGHTER INJURIES DUE TO FIRES
(Total Number of Injuries)

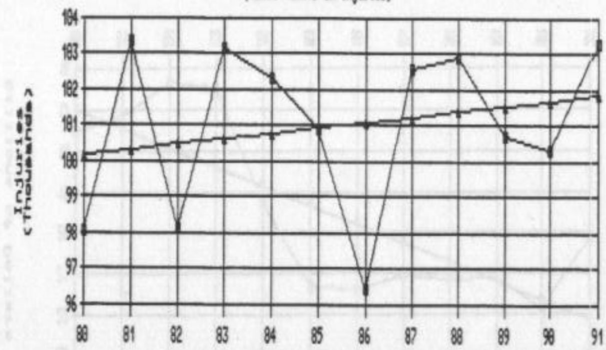


Figure 12: 1980-1991
□ Actual Data ▲ Least-Squares Fit

MANAGEMENT ISSUES IN EMERGENCIES

A MISSING COMPONENT IN YOUR EMERGENCY MANAGEMENT PLANS: THE CRITICAL INCIDENT STRESS FACTOR

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ABSTRACT

In emergency management, the effects of stress on the performance of emergency personnel, typically have been ignored or regarded as too enigmatic to quantify. This paper discusses the concept of Critical Incident Stress in responders to emergencies. It presents the rationale for considering stress as a significant factor in the management of emergencies. It is proposed that Critical Incident Stress Debriefing in a disaster can improve the effectiveness of response teams on site, their turnaround time on site, and post-disaster time off the job. Critical Incident Stress intervention also can mitigate potential deleterious emotional effects associated with emergency work. This paper, prepared by a U.S. Bureau of Mines researcher, offers some ideas to the mining industry in general, to mine rescue team trainers, and to developers of program simulations on the specific issue of how people, time, materials and space may be factored into a plan for emergency management. The impact of stress on emergency workers is presented as a missing component in present emergency management models.

INTRODUCTION

A main focus in the management of emergencies has been on resources and logistics, on providing the necessary resources to meet a crisis within an urgent time frame; in other words, having **what** and **who** you need, **where** and **when** you need it. The necessary resources include trained manpower, appropriate equipment, available communication, plus knowledgeable and decisive leaders. In the mining industry, emergency response planners have concentrated on designing better and safer equipment, on producing rescue apparatus such as the person-wearable, self-contained self-rescuers, on decreasing response time, on increasing training of mine rescue teams, and on developing escape plans that comply with mine safety regulations. Mining operators must develop escape plans that are designed to comply with regulations under 30CFR Part 75 (sec 1101-23 and 1704-2).

Immediate and appropriate response to mine disasters is, of course, essential. "Longer hoses and higher ladders" are important. New technology and increased training improves the efficiency of the rescue worker. An often missing consideration in mine and other disaster training and management programs however, is the impact of stress on the emergency workers themselves. This paper offers information and proposes how the effects of human stress on emergency\rescue workers may be factored into emergency management planning.

THE RATIONALE FOR INCLUSION

The stress response is a normal human characteristic, an adaptive preparation for action by humans in crisis. The human organism survives because of the maintenance of a normal internal balance referred to as homeostasis. A physical or psychological threat tends to disrupt homeostasis and produce physiological reactions in the body. These physiological reactions involve the nervous and endocrine systems and produce various system, and organ responses. Specifically, stress leads to activation of the autonomic nervous system and to an increase or

1 - 2% (10). The general statistical risk of PTSD, however, can be misleading. For those in high risk professions, any single traumatic incident may engender symptoms of post-traumatic stress or fully developed PTSD, at an incidence up to 90% or more in those who are primary or secondary victims. (8)

By definition, a traumatizing event is one that is outside the normal range of everyday life events. It is experienced by the individual as overwhelming. (11) Traumatizing events or **critical incidents** are especially frequent among emergency workers. A critical incident is one experienced by personnel that produces an emotional reaction with the potential for inhibiting a worker's ability to function either at the scene or later. (12) An example of a critical incident would be the serious injury or death of a colleague in the line of duty or an incident where the circumstances, the sights, sounds and smells are so distressing as to result in an immediate or delayed reaction. (12)

Researchers have identified both immediate and long range symptomatic reactions to trauma. (11) Initially, individuals will report numbness, denial, avoidance of places or things that remind them of the trauma, withdrawal from social interaction, depression, difficulty with concentration and relationships. Long range, more acute symptoms include fearfulness, irritability, sleep disturbance, flashbacks and heightened sensitivity. These responses can fluctuate within an individual and be confusing and disturbing. Although researchers and psychologists who specialize in job stress generally agree that persons attracted to emergency work are, as a group, basically more emotionally stable than the general population, emergency workers, however are subject to an increased incidence of stress-related diseases such as heart disease. (13)

Generally, emergency workers close ranks after a crisis. They prefer to talk to others in their unit or on their rescue team. Telltale signs of distress such as excessive humor, increased derogatory remarks against one another, irritability, withdrawal from others or significant changes in behavior are often overlooked by peers. Post trauma reactions are natural - though not necessarily healthy - responses to trauma, and they can be resolved. There is consensus among clinicians and researchers that the presence of a supportive environment is crucial to a positive resolution for the traumatized worker. (11) Successful resolution of the crisis experience not only allows for the worker's return to productive work but can help him or her better understand a

Figure 1.--Miner's escape through smoke

normal response to an atypical situation. Emergency Service personnel generally are normal individuals responding to abnormal situations. Critical Incident Stress Debriefing is an organized approach to the management of the stress reaction.

BACKGROUND

Throughout history there are references to human stress in traumatic situations. According to Mitchell, Critical Incident Stress Debriefing intervention evolved from four major influences: military experiences, police psychology, emergency medical services and disasters. (14) Mitchell noted that stress reactions during war have been reported by historians since 603 BC.

meet with mental health professionals and are given information on the typical effects of critical incident stress and the symptoms which may or may not appear. They are given practical suggestions for stress management and allowed time to comment or ask questions.

Post-incident CISD

For about 24 hours after an incident is over and defusings or demobilizations are complete, emergency personnel typically prefer not to discuss the event with outsiders. Emergency personnel may focus on reports and procedure, not being ready to deal with their feelings about the event. (15)

As stated earlier, CISD is a psychological and educational support group discussion that utilizes a specially trained team composed of a mental health professional and peer support personnel. A CISD team after a mining disaster would be composed of a mental health professional and mine rescue team members who have been trained in CISD. The CISD is a carefully designed, structured process that progresses through seven phases and provides stress-reduction information. Participants are encouraged, but not required, to speak; the process is confidential. (16)

Responders to emergencies are not always trained or experienced personnel. Sometimes they are individuals who simply are "there" and enlisted to perform a task. In a mine fire, rank and file miners from other areas may be called upon to execute emergency assignments and consequently be exposed to critical incidents. An example of this assumption of roles in an emergency, is found in a U.S. Bureau of Mine's case study of workers' escape from an underground mine fire (17). The fire was discovered by the "fire boss" (mine examiner) who disengaged the trolley power and called to warn the shift foreman and the miners working in the three sections which were affected by the fire. The fire boss, joined by the mine foreman and the general assistant foreman fought the fire and extinguished it about an hour after discovery. Meanwhile, twenty-some miners escaped under smoke. There was no time for a mine rescue team to organize and respond. The individuals on the scene reacted to fight the fire and to execute the escape. All individuals called upon to fulfill emergency roles should be included in debriefings.

Follow-up

All defusings, demobilizations and debriefings are followed up in some manner ranging from a phone call to a follow-up meeting.

A CISD team must be trained. It takes a special task force six months to a year to organize a CISD team. They need to be carefully recruited, trained, and committed to the process. (14)

FURTHER INFORMATION

Critical Incident Stress Debriefing teams have grown remarkably in the past ten years. The Second World Congress on Stress Trauma and Coping in the Emergency Services Professions, held in 1993 in Baltimore, MD attracted attenders from all over the United States and abroad. In January of 1994 there were approximately 350 CISD teams worldwide. (18) The studies cited here suggest that those responsible for the development and implementation of crisis management plans need to be aware of the importance of including resources for meeting the critical incident stress potential for their rescue workers. They emphasize the importance of the intentional creation of pre-incident education programs and a post-trauma workplace milieu that is conducive to healthy resolution of the trauma.

Management personnel are not exempt from critical incident stress syndrome. As reported by Doepel, managers are vulnerable to traumatic stress reactions and need to be offered training and information with the rest of the emergency personnel. (11) His experience suggests that management, whenever possible be involved in the group process. He concludes that a good emergency plan "is enhanced by the inclusion of components designed to mitigate the effects of post-traumatic stress reactions among managers and employees" (11 p. 186).

RESPONDING TO DISASTER DURING CONFLICT:
NEED FOR CHANGES IN DISASTER MANAGEMENT TECHNIQUES

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ABSTRACT

Responding to conflict disasters is different from dealing with non-conflict emergencies. Getting to the scene of a conflict to assess needs and manage assistance can be impractical. Response efforts may encounter active opposition from those pursuing the conflict. The paper summarizes the current concepts of disaster management, reviews the nature of conflict disasters and identifies what distinguishes conflict from non-conflict disaster management. The paper concludes that the objectives and tasks of a disaster management organization make it part of a conflict situation. The paper proposes that assuring security, securing access and resource control are core strategies in conflict disaster management. Humanitarian assistance may contribute to prolonging a conflict. In the extreme, an agency devoted to helping disaster victims must ask itself whether it can hasten an end to hostilities and to the conflict-related disaster by withdrawing, rather than continuing to provide, assistance.

INTRODUCTION

"Conflict disasters" are absorbing an increasingly large part of international disaster assistance efforts (1, 2). These disasters differ from non-conflict disasters because of the threatened or actual violence arising from the conflict. This violence makes conflict disaster management efforts more difficult and hazardous than non-conflict disasters. Providing humanitarian assistance despite the threat of violence requires changes in the way in which disaster response in managed.

DISASTER MANAGEMENT CONCEPTS

Cuny defines disaster management as ". . . activities designed to maintain control over disaster and emergency situations and to provide a framework for helping at-risk persons to avoid or recover from the impact of the disaster . . ." (3). Effective disaster management occurs in a continuum covering response, recovery, prevention, mitigation, preparedness and warning periods (4). Disaster response operations focus on a quick return to a <u>status quo ante</u>. A disaster also provides opportunities to foster the development of an affected population and reduce vulnerability through preparedness and mitigation activities (5).

Operationally, disaster management focuses on four sets of activities: 1) Assessing who is affected, to what degree and where they are located; 2) Defining response requirements and plans; 3) Acquiring and delivering resources; and, 4) Supporting use of the resources provided.

Disaster management is time sensitive. Actions must take place within a specific time to minimize negative consequences. To be timely, appear to be greater than in the past.

Ways of causing disaster during a conflict range from indirect (e.g., blockades) to direct (e.g., bombing). Where one side cannot secure immediate victory, a strategy to weaken the opposition through indirect or low intensity military actions can develop. This strategy uses less directly confrontational actions to create disaster conditions in an opponent's area of influence over a longer term. Core to this strategy is the denial of supplies required to sustain normal society by a restriction of commercial and relief activities, and the destruction of food supplies and infrastructure. In cases such as a besieged city or region, a selective denial of supplies may be used by those holding the city to maintain a state of disaster among potentially hostile inhabitants of the city (18).

The effects of a strategy of denial are not immediate. Targeted populations do not often live day-to-day and they have residual supplies to use in coping with shortages resulting from the conflict. As a result, conflict disasters can develop slowly as supplies are depleted, reaching a stage where dramatic events occur, such as a severe worsening of health and welfare and mass migrations.

Many conflicts occur in areas with limited in resources such as food, logistics, health care, or funds. In these areas, non-combatants can become willing or unwilling sources of resources to support a conflict. This taking of resources can also further the objective of creating disaster conditions. Assistance organizations with significant resources in a conflict area become targets for the taking of resources.

Distinguishing the conflict and non-conflict causes of a disaster may be difficult. Conditions that constitute a disaster in times of peace may improve the effectiveness of efforts to create a disaster during a conflict. As a result, there is no real difference between dealing with conflict disasters and non-conflict disasters that may occur in an area affected by a conflict.

Anderson proposes that solving conflict disasters lies in establishing peace (19). However, establishing lasting peace is a political process that can require lengthy negotiations. Conceivably, the longer and more severe a disaster is, the better one party's negotiating position becomes. Efforts to make disaster conditions worse may increase during peace negotiations while possibilities for providing assistance become more limited.

Disaster Management During Conflict

Disaster management attempts to avoid disasters. In a conflict, at least one party tries to create disaster conditions. Despite this conflict of purpose, disaster management efforts do occur during conflicts through three mechanisms:

1) by consent of the conflicting parties, but only when parties expect no advantage to the opposition from the provision of assistance (20);

2) by force, through the use of armed forces to neutralize opposing parties; or,

3) as partisan support for one party in a conflict.

Ideally, providing assistance

approaches to assuring security can be considered:

1) Establish a position of force greater than the opposed parties through external or locally recruited armed personnel. This, of course, has the risk of making the assistance providers an active party to the conflict.

2) Aligning with one party in the conflict, thus making use of their security capacity for protection, however with an increased risk of violence from the opposition.

3) Operating a transparent operation where plans and decisions are approved by all parties to a conflict. This provides for a continual confirmation of unhindered assistance. However, this approach neither permits quick action nor avoids manipulation by the opposed parties by withholding approval for specific activities (31).

Choosing the best approach depends on the specific circumstances of a conflict and the willingness of those financing assistance to underwrite costs. In choosing to provide assistance, an organization may need to change its humanitarian and administrative policies to allow field personnel flexibility and latitude in delivering assistance in the most effective and least risky manner appropriate.

Securing Access

Those financing disaster response often place a particular emphasis on access to affected areas to assess needs and oversee and evaluate assistance. Access is key in verifying that aid is fairly distributed and victims are not alienated from management of the disaster continuum. Access is also key to securing financing and popular support for assistance through visits by media and decision makers.

As the denial of access is one of the basic means of creating a conflict disaster, providing access to a conflict area poses risks for those responsible for these efforts. Thus, the strongest efforts may be made to prevent access to areas where need is greatest.

Securing adequate access to conflict areas requires the same approaches to assuring security discussed above, with the same associated problems and risks. Where direct access is not feasible, technology may provide some ability to assess needs and deliver assistance. For instance, remote sensing can provide data to assess disaster impact, aircraft can deliver limited supplies and radio broadcasts can provide information on the use and availability of relief, although at a higher cost than direct access.

However, disaster management technologies cannot replace all requirements for direct access. Using technology to overcome access problems may also be seen as giving an advantage to one side of the conflict and subject assistance providers to sanctions. Effectively dealing with access problems may require changes in an organization's policies to permit tradeoffs between accountability and the delivery of assistance to inaccessible areas suspected of requiring assistance.

Control of Resources

In resource poor areas, assistance providers can be better endowed with communications, vehicles, food, medical supplies, fuel and other resources than the other parties to the conflict. These resources may provide a means

- 199.
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resources. When an organization enters a turbulent environment (such as a disaster) normal exchange links are disturbed (Gillespie and Mileti, 1979). An organizational network is therefore a cluster of organizations in an environment, clusters built around stable and repeated exchanges. To understand the complex decision-making process of organizations, the notion of networks can be perceived as an integrative function of resources. (Hellgren and Stjernberg, 1987).

Organizations in a network trying to respond to the demands of a disaster create a mega-organization. A mega-organization is a relatively new theotical concept (Denis, 1993) created to understand how organizations unite. It does not presuppose any specific types of relationships (conflict, cooperation, etc.) or any dependance. It is used to see that an organization alone cannot respond to a disaster and that links are established between different organizations in a disaster.

Although resources are scarce and concentrated, the organizational environment is a source of uncertainty for organizations. The level of uncertainty is linked to existing dependance and power relationships between organizations (Hellgren and Stjernberg, 1987). Uncertainty is also linked to the perception of the organization that is faced with turbulence. Uncertainty is therefore subjective, according to the diagnostic and the evaluation of the capacity of the organization to respond. A distinction must be made between uncertainty and turbulence. Turbulence is movement and uncertainty is turbulence transformed into a constraint, with a perception of incapacity of action, potential or real (Denis, 1990).

Interorganizational networks are therefore a way in which organizations can obtain resources to face turbulence and uncertainty in the environment. Green, Neal and Quarantelli (1989) from the analytical model of Evan (1976) have established a typology of networks. Five types of networks are identified, according to the degree of centrality of the network (all-channels, circle, chain, Y and wheel).

The position of an organization in the network is an important indicator of the power it has on its environment. Consequently, an organization's influence depends not only on scarce resources, but also on the position it holds in the network (Milward, 1982; Cook, 1977).

Typology of issues in disaster management

All disasters imply issues to be dealt with for recovery. Issues can be categorized in three: technical, socio-political and scientific. Technical issues are relative to dealing with the source of danger, for example firefighting, rescuing victims, etc. Socio-political issues involve social aspects of dealing with needs of the victims and the community: evacuation, shelter, health care and information. The political aspect is between the elected officials and the victims. Finally, scientific issues consist of the fundamental research required to solve problems such as sampling, analysis and interpretation of results. Each of these categories present a certain degree of complexity, turbulence and often uncertainty.

The notion of interorganizational networks is a practical way for analyzing the mega-organization. For each category of problems, an organizational field is created because of an interdependence of resources or because an exchange of resources is necessary. By observing the behavior of organizations in two disasters, we will attempt to demonstrate if the mega-organization was able to respond effectively to the demands created by the disasters.

3. Methodology

This research is exploratory and is based on a qualitative method of analysis. The choice of a qualitative method was imperative because of the complexity and the large quantity of data. Many documents from the provincial emergency office (Direction générale de la sécurité civile) were used for a first analysis. Two monographs of the two disasters were prepared by using the different stages of the disaster, creating a "movie" of the event.

Eighteen semi-directive interviews were conducted with emergency managers directly involved in either disaster. Articles, media releases and internal reports of different organizations complete our sources of information.

A first level of analysis consists of the description of each disaster, using the typology of issues so that in each category can be established interorganizational networks. The second level of analysis is a comparison between the two disasters. Issues are compared to each other in order to explain the differences between the type of coordination used in each disaster.

4. Analysis and finding

The St-Amable fire

May 16th 1990, a fire is discovered in a used tire dump in the small town of Saint-Amable (around 5000 residents). The fire touches about 4 hectares. The alone. Other organizations had vital resources and exchanges were necessary. For example, this small municipality did not possess all of the resources to conduct an evacuation, many volunteer organization were asked to help and were directed by the provincial police force. The central role played by the Canadian National Railway (CNR) was important in the exchanges of resources. Although it did not manage the event in an autocratic way, a form of power could be detected. Organizations implicated in technical and socio-political issues were dependant of the re-railing of wagons (by CNR). CNR gave the sequence of its operations and all other activities depended on them, and thus these activities created interdependence between issues.

Comparison between the two disasters and general observations

Comparison between technical issues

Clearly, the two disasters were not managed the same way, although their origins lie both in technology. For technical issues, in the tire dump fire was managed by ministries; in the train derailment the Canadian National Railway managed technical issues with the help of provincial ministries. This situation can be explained by the fact that the rails belong to the CNR. But, the land where the tires were stored also belonged to a private company, and the provincial government intervened in the management of this disaster from the beginning. This small business did not have the same type and amount of resources as the CNR (federal government corporation).

Social acceptability of these disasters

Generally, the management of disasters in Québec are coordinated by the regional director of the provincial emergency services office after a demand from the municipality. The coordination of the St-Amable fire dump was carried out by the deputy minister and not by the regional director. The coordination of the train derailment was handled by the regional director and by the CNR. This difference makes us think that the conditions around the management of the fire were less acceptable socialy.

Uncertainty and network types

Uncertainty surrounding the train derailment was less important although the danger was more important. This demonstrate how uncertainty is subjective to organizations. But this is a partial explanation. For the train derailment, CNR was present since the beginning and cooperated with the municipality, joined the coordinated committee, contributed resources and assured coordination of technical issues. In the tire dump fire, the emergency services office arrived many hours after the beginning of the incident and did not possess the necessary resources. It sought them through other organizations and then assured their coordination. We can say that an all-channels networks can be efficient if the central organization assumes a coordinating role and that it has good coordinating experience.

In both disasters, the technical issues were characterized by all-channels networks. Uncertainty was not as important in the train derailment because the impact was known. Uncertainty in an all-channels network is linked to the perception of organizations, to the roles played by organizations, to the intensity perceived by managers and by the population. An all-channels network could intensify uncertainty if no local organization coordinates resources.

Comparison between socio-political issues

Public and media information

Information for the public was not treated in the same way, even if in both cases press conferences were held regularly with the population and the media. Information was given to the people of St-Léonard d'Aston since the beginning of the event and press conferences were given at the same time each day. At St-Amable, the confusion at the beginning of the event left the population and the disaster managers with a lack of information even if press conferences were held at regular times afterwards. This situation is a partial explanation of the lack of acceptance of the situation by the population of St-Amable. This non-acceptance can also be explained by the lack of information in the beginning. This situation was unacceptable because the government knew the risk the tire dump represented.

The media treatment was very different in both cases. The St-Amable fire received provincial coverage. Because the situation was known by the government, the media looked for the guilty party. Also, St-Amable is closer to Montreal (40 km) than St-Léonard d'Aston (200 km). St-Léonard d'Aston received local attention from the media. Another explanation can be put foreword. On December 6th, the massacre of 14 young women took place at an engineering school in Montreal (Ecole Polytechnique). This event was covered intensely for several days, and the train derailment happened on December 12th. This put the train derailment as a secondary event although it

RISK MANAGEMENT

SELECTING THE MINIMUM RISK ROUTE IN THE TRANSPORTATION OF HAZARDOUS MATERIALS

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ABSTRACT

The transportation of hazardous materials is a broad and complex topic. The number of accidents involving vehicles carrying hazardous goods is increasing. Modern computer based information systems are frequently utilized for materials management. This paper presents an interactive software system for the minimum risk route selection based on the PC ARC/INFO Geographic Information System. The model computes optimal paths based on road network geometry and technical characteristics (road width, radius, and slope), class of hazardous materials, and environmental sensitivity. Hazardous materials are classified into categories according to their impact on different environmental elements. Regulatory requirements of the Hazardous Materials Transportation Act are also presented in detail in order to provide a broader understanding of the complexity of hazardous material transport.

GENERAL

Federal laws impose comprehensive requirements on the transportation of both hazardous materials and hazardous wastes. Primary responsibility is assigned to the United States Department of Transportation (USDOT), which administers the Hazardous Materials Transportation Act (HMTA). HMTA was initially adopted in 1974, replacing earlier legislation and expanding upon USDOT's general responsibility to ensure the safe transport of goods in interstate commerce. HMTA applies to most forms of transportation including rail, motor vehicles, aircraft, and vessels. Pipeline transportation is regulated separately under the Natural Gas Pipeline Safety Act. HMTA was most recently amended in 1990 by the Hazardous Materials Transportation Uniform Safety Act of 1990.

USDOT has assigned the responsibility for promulgating HMTA rules to its Research and Special Programs Administration (RSPA). In recent years USDOT has been revising many HMTA regulations to make them clearer and more consistent and to increase the uniformity between domestic requirements and those imposed on international shipments by countries that follow the United Nations Recommendations on the Transport of Dangerous Goods (UN Recommendations). These revisions are being created through a number of related rulemakings.

Although HMTA applies to hazardous materials and hazardous wastes, the United States Environmental Protection Agency (USEPA) also regulates hazardous wastes transport as part of the USEPA's administration of the Resource Conservation and Recovery Act (RCRA). RCRA authorizes the USEPA to issue additional requirements to meet the special risks associated with hazardous waste transport. USEPA, however, must ensure that its regulations are consistent with those published by the USDOT.

HMTA generally provides that federal requirements preempt inconsistent state standards. This provision is intended to ensure that interstate transportation and commerce are not disrupted by state and local variations. States can adopt provisions that are "substantially the same" as federal standards. USDOT has the authority to issue a determination of consistency allowing the state and local governments to enforce existing requirements.

HAZARDOUS MATERIALS TRANSPORTATION ACT

USDOT regulations are organized in two overlapping ways. They address both the range of activities involving hazardous materials and the individuals and corporate "persons" who actually undertake these activities. Current USDOT regulations cover the following activities:

- the manufacture of packaging and transport containers;
- labeling, marking, or placarding of containers and vehicles;
- handling (including packing and unpacking, loading and unloading, and procedures during transport;
- training of transport personnel;
- registration of highly hazardous materials transport;
- restriction or designation of hazardous materials transport routes (by state and local agencies, following federal standards);
- spill reporting implemented by USDOT along with EPA and the Federal Emergency Management Agency (FEMA); and
- the demonstration of financial responsibility.

Defining Hazardous Materials

HMTA defines hazardous materials as those designated materials that might create an "unreasonable" risk to health and safety or property when being transported. Regulated materials designated by USDOT include any of the hazardous materials listed in USDOT regulations (49 Code of Federal Regulations sections 172, 101, 172, 102) and the Comprehensive Environmental Response, Compensation, and Liability Act of l980 (CERCLA) hazardous substances listed in the Appendix to section 172. The USDOT list also incorporates by reference hazardous wastes subject to EPA "manifest" requirements.

Generally, HMTA regulations cover the "transportation in commerce" of any amount of a designated hazardous material. However, the degree to which regulations are applied to a given shipment depends on the hazard class of the material, the quantity of material being shipped, the type of carrier, and the type of contained holding the hazardous

Although the packaging and labeling requirements are intended to reduce the likelihood and harm of spills and other transportation emergencies, HMTA imposes additional requirements specifically to facilitate a quick response in case of an emergency. USDOT expanded the emergency response duties of shippers of hazardous materials effective December 31, 1990. First, these regulations require that each shipment be accompanied by emergency response information useful in mitigating a spill, including the following for each hazardous material transported:

- a description and the technical name of the hazardous material, as required on the shipping papers;
- immediate hazards to health;
- risks of fire or explosion;
- immediate precautions to take in response to an accident;
- immediate methods for handling fires;
- initial methods for handling spills that do not involve a fire or explosion;
- preliminary first aid measures.

This information must be available on the transport vehicle, away from the materials themselves and immediately accessible to the transporter and agency personnel (e.g., in the truck cab) for use by emergency response personnel.

In addition to taking these precautions involving the transport vehicle, each "person who offers a hazardous material for transportation" must provide a 24-hour emergency response telephone number monitored by personnel able to provide callers with additional information regarding the hazardous materials being transported, and proper emergency response procedures. USDOT's regulations provide that this number need only be monitored while materials are actually being transported. (Many shippers contract with third-party chemical information services to meet this requirement.)

Entities involved in hazardous materials transport are usually required by other laws to prepare for emergencies and emergency response. Examples include RCRA contingency plans and Clean Water ACT (CWA) requirements for spill prevention control and countermeasure (SPCC) plans, and Facility and Vessel Emergency Response Plans.

Reporting Transportation Incidents

Carriers must notify appropriate agencies of transportation incidents. Generally, immediate notification is required if an incident causes death or serious injury, more than $50,000 in damage, public evacuation, or the release of radioactive materials or etiologic agents. An immediate telephone call must be made to the National Response Center and to the Department of Community Affairs, Division of Emergency Management. Detailed written reports of all incidents and spills must be made to USDOT within 30 days (on USDOT Form F5800.1). These reporting requirements are in addition to similar EPA-administered requirements under RCRA and Superfund.

Driver and Vehicle Standards

USDOT regulates hazardous materials carriers as an extension of its regulation of motor vehicles. USDOT regulations also include technical requirements for the construction of transport containers, equipments, and vehicles for each mode of transportation--highway, rail, air, and water. Vehicles must also meet minimum safety requirements for lights, brakes, and other operating equipment in addition to following a proper maintenance schedule. The regulations also outline loading, unloading, and general handling procedures for each mode.

HMTA regulations address drivers' qualifications based on a physical examination, driving record, and written and driving tests. States generally adopt these standards, although some impose additional training or experience requirements.

Training "Hazmat Employees"

The 1990 amendments direct USDOT to expand training required for personnel involved in loading, unloading, handling, storing, and transporting hazardous materials as well as emergency preparedness for responding to accidents involved hazardous materials--the law refers to these employees as hazmat employees. The 1990 amendments provide that this training should not conflict with any training required by the US Occupational Safety and Health Administration (OSHA; see A2) or EPA. USDOT initially issued these "HM-126F" training rules on May 15, 1992 and then deferred their implementation (58 Federal Register 5850, January 22, 1993).

Employers must certify that employees have been trained and tested in any of the following areas applicable to their jobs:

- recognition and understanding of USDOT's hazardous materials classification system;
- use and limitations of the USDOT hazardous materials placarding, labeling, and marking systems;
- general handling procedures, loading and unloading techniques, and strategies to reduce the probability of damage or release during transportation;
- health, safety, and risk factors associated with hazardous materials and their transportation;
- emergency response and communication procedures for transport accidents;
- use of USDOT's Emergency Response Guidebook;
- hazardous materials transportation regulations;
- personal protection techniques;
- preparation of shipping documents.

Hazmat employees working as of July 2, 1993, must receive their initial training by October 1, 1993; employees hired after July 2, 1993, must receive their training within 90 days of employment. (USDOT's initial HM-126F rules made November 15, 1992, the effective date; USDOT deferred implementation in response to a number of petitions to have implementation dates for training requirements coincide with the deadline for the new labeling standards described above.) Employees who change job functions must receive any training required for their new job functions within 90 days. New or transferred employees must remain under the supervision of a trained employee or until they complete their own training.

- at the destination, the transporter ensures that the receiving entity signs for the waste, then keeps one copy and gives the other two copies to the destination facility.

A transporter must retain the transporter's copy of each manifest for a minimum of three years calculated from the date the waste is first accepted by the initial transporter.

Third, RCRA requires that transporters take certain actions in response to hazardous waste discharges during transport. They must inform appropriate federal, state and local agencies of the spill, and are also responsible for immediate containment actions (e.g., diking a spill area), although emergency response agencies typically assume site command once they reach the scene of the spill. Transporters retain legal and financial responsibility for cleanup. Transporters of hazardous waste must prepare contingency plans and train personnel in spill response procedures.

RCRA's general inspection, record-keeping, and enforcement provisions apply to transporters; thus, a violation of a legal requirement may result in criminal and/or civil penalties.

AN AUTOMATED APPROACH

The number and gravity of accidents involving vehicles transporting hazardous materials is increasing. As previously noted, extensive regulations are in place to comprehensively address hazardous material transport. In order to further protect the health, safety and welfare of the public as well as the environment, additional safeguards must be taken. For this reason, support from a modern computer-based information system is necessary. In conjunction with regulations for the transportation, personnel, and packaging dealing with hazardous materials, the selection of an optimal transportation route can assist in improving transportation safety. A minimum risk route selection application can be developed as part of more complete spatial information systems.

Data Model

The following databases must be developed as part of the overall system development:

- hazardous materials database,
- road network database, and
- environmental impact database.

An area's environmental sensitivity differs according to the category of hazardous material. This model utilizes the same categories developed by USDOT based on international standards. The model considers environmental sensitivity of water resources, air resources, human population, cultural resources, and land (upland/wetland) resources. Information regarding hazardous materials must include at a minimum, USDOT category, chemical name, and international codes.

Road Network Database

The extent of a local road network enables transport of hazardous materials. The condition of the road network and associated network geometry determines the relative safety of transportation operations. Primary and secondary roads are necessary to develop the network database. Graphically, this information may be derived from digitization of street centerlines. The following road data is necessary for transportation optimization:

- horizontal curvature,
- vertical alignment,
- width, and
- construction.

Local conditions may dictate parameters by which certain roads may be eliminated from consideration in the transportation network.

Environmental Areas Database

While exposure to hazardous materials poses a risk to the general population and environment, there are certain elements of the human and natural environment that we may want to specifically protect due to rarity or other status. Environmentally sensitive areas may be mapped from local, regional, and state mapping sources.

Environmental Sensitivity Model

In many areas, different elements of environmental sensitivity may occur. For example, major groundwater supplies may be located in an area of threatened and endangered species or sensitive wetland habitat. Such areas where several elements are allocated must be modeled to reflect the confluence of several elements. GIS technology allows for the consideration of multiple databases. Utilizing topological overlay, multiple elements may be evaluated. Local conditions will determine the weights assigned to sensitive elements.

Optimal Path Selection

In the case that the transportation of hazardous materials cannot be avoided and alternative transportation routes cannot be avoided, an optimal path, which represents the minimum risk to sensitive elements, must be determined. This determination is possible by combining the road network database and environmental model database. Each section in the road network contains information regarding operating speed and the length of the section. The optimal path between an origin and destination is the route that has the minimum cumulative value of expression where: impedance = length/operating speed x vulnerability. Vulnerability depends on the class of the dangerous material.

GIS enables the determination of hazardous material class based on international code and chemical name and the selection of the appropriate road network based on vehicle type. The GIS database can also contain the origin and destination points based on address range information.

CONCLUSION

The transportation of hazardous materials represents a major threat to the environment. With the aid of GIS for decision support in transportation, this risk may be minimized. Additional databases may be developed to allow for a more comprehensive evaluation of risk.

MONTY: A Monte Carlo Method for Quantitative Risk Assessment

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Abstract

This paper describes a Monte Carlo approach developed by the authors to address problems of quantitative risk assessment (QRA) in complex settings. The method has been implemented in the program MONTY which provides a flexible framework for investigating a wide range of industrial risk assessment problems (chemical plants, pipelines, transportation corridors etc). The method provides a predictive tool for estimating individual and societal risks of interest in plant design, emergency management and policy formulation. Analytical procedures have been developed to provide a basis for investigating the sensitivity of risk estimates to model and parameter uncertainties. Several cases studies have been conducted to compare the performance of the Monte Carlo approach with conventional QRA analysis. The results of a study involving flammable and explosive risks from a hexane/heptane distillation column are presented.

1. Introduction

In quantitative risk assessment (QRA) we are concerned with calculating the risk to people (in terms of injuries or deaths) or property (in terms of cost) resulting from industrial accidents.

Typically these problems involve the following steps: specifying the structure of the system to be analyzed (eg layout of a chemical plant); developing plausible scenarios for the cause of accident events (eg fault trees); estimating the statistics associated with the occurrence of events (eg magnitude/frequency relationships); calculating the physical effects arising from these events at a distance (eg dispersion modelling); and, calculating the effects of the event on exposed humans or structures (eg toxic dose modelling).

In principle the QRA problem is relatively straightforward and only requires that each part of the problem be adequately specified and the consequences of the various accident scenarios systematically evaluated. However, in practise this can be a formidable and often intractable task due to the complexity of the systems involved and the large numbers of possible cases that need to be considered.

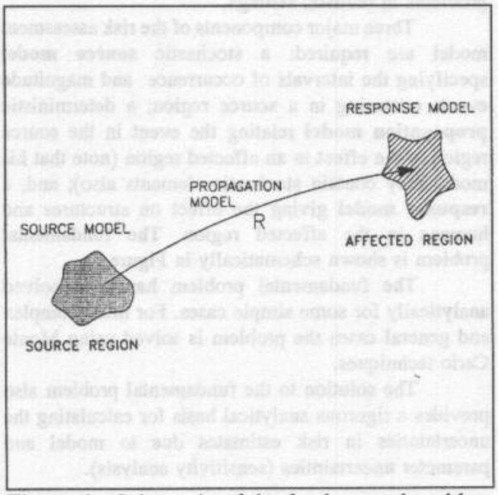

Figure 1 - Schematic of the fundamental problem in quantitative risk assessment.

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model resulting from an accidental release. These are taken form various sources. Many publications provide a wide range of possible consequence models for use in MONTY [see CCPS 1989].

The trials represent the basic simulation events in MONTY. Individual accident events are simulated for each source and class to provide risk estimate statistics.

3. Case Study

The case study considered here is taken from CCPS [1989] (Case Study 8.2 pp 443-477). The problem concerns the risks associated with the flammable materials in a C_6 distillation column used to separate hexane and heptane from a feed stream consisting of 58% (wt) hexane and 42% (wt) heptane (see Figure 3 for flow rates and line sizes). The overhead condenser, thermosyphon reboiler and accumulator are considered in this study.

The column operating pressure is 4 barg and the temperature range is from 130-160C from the top to the bottom of the column, respectively. The column bottoms and reboiler inventory is 6000 kg (roughly 5 min of holdup) and there is about 10,000 kg of liquid on the trays. The condenser is assumed to have no liquid holdup and the accumulator drum inventory is 12,000 kg (roughly 10 min holdup of feed rate). The material in the bottom of the column is approximately 90% heptane and 10% hexane. The relevant physical properties for these materials can be found in CCPS [1989].

The plant site layout is shown in Figure 4. To the east of the column, at a distance of 80 m, there is a residential area containing 200 people, distributed uniformly on 100 m by 100 m. The remaining area around the site consists of open fields.

The objective of the study is to estimate the risk to the residential community from the fractionation system from both the individual and societal risk perspectives.

The sources considered in this problem included: an instantaneous release (complete inventory loss) and a continuous release (11 kg/s). The statistics for the frequency of occurrence of events were taken from CCPS [1989].

The classes considered in this problem include: BLEVEs, jet fires, flash fires (instantaneous and

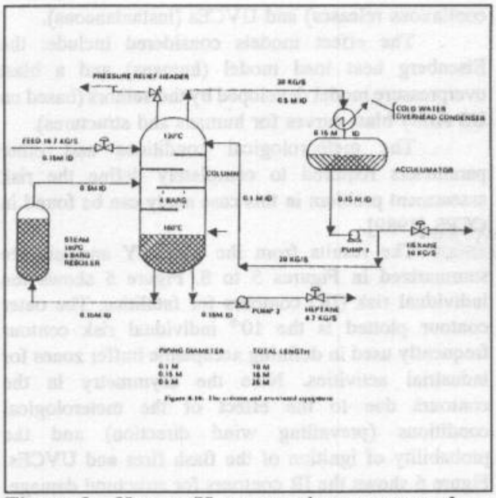

Figure 3 - Hexane/Heptane column case study

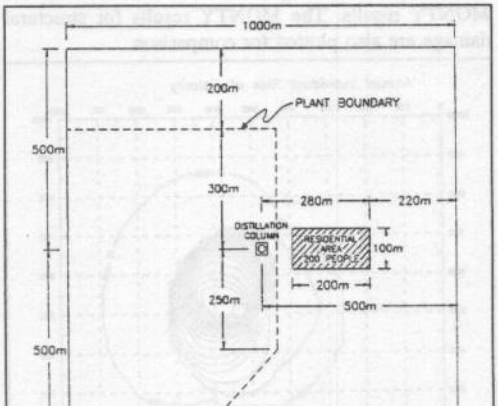

Figure 4 - Heptane/hexane distillation column example.

4. Summary

The summary of results presented here includes conclusions obtained from the more extensive study of the Monte Carlo approach as outlined in Hilbert [1994] and the investigation of the solution of the fundamental problem in QRA contained in Ramsay & Hilbert [1994b].

Based on the results obtained in these studies the following conclusions are emphasized:

1) The Monte Carlo approach to quantitative risk assessment implemented in the program MONTY provides a powerful tool for investigating a very general range of industrial risk assessment problems.

2) The analytical solution of the fundamental problem in QRA provides a rigorous mathematical basis for the Monte Carlo approach and an extensive analysis of the uncertainties in risk estimates due to model and parameter uncertainties.

3) The methodology developed in this study, considering the whole process of generation of an event, propagation from the source region to an affected region, and the response of structures and people, provides a powerful and effective tool to study chemical process risk in its broadest form.

4) The representation of the mean return periods is quite adequate of the prediction of risk at a point.

5) The final probability characterizing risk at a point is influenced by many parameters some of which are uncertain. For probabilities of exceedence not smaller than 0.01 the final distribution of extreme values of response is mainly influenced by the event generation process. But for smaller risks, the non-linear behaviour of the response given the intensity of excitation, affects considerably the final probability distribution of risk.

5) Risk at a single point does not indicate the potential damages from an event for an area.

6) Risk for an area must be defined in terms of a global quantity (i.e. total losses). No single parameter has been identified to represent this risk in simple terms. The entire probability distribution should be considered in this case.

6) The concept of a continuous damage function as developed in Ramsay & Hilbert [1994b] is a very fundamental tool to be used in risk analysis. It reflects important features of the damage-response interaction; therefore, it constitutes an important element in the study of losses.

RISK MANAGEMENT OF COMPLEX TECHNOLOGICAL SYSTEMS: TOWARDS A SOCIO-ENGINEERING APPROACH

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ABSTRACT

Engineers and social scientists have addressed risk management of technological systems in many different ways. In this paper we will argue that all of these approaches offer significant insights, but that there are also shortcomings when safety issues are approached within only one discipline. The ever increasing complexity of large-scale problems calls for a more comprehensive approach to safety management. One-dimensional thinking cannot cope with the intricate interconnections among various decision makers and levels of decision making, diverging value-systems of different stakeholders, and hazardous (complex) operations.

This paper discusses an influence diagram and a multi-level model for disaster analysis applied to an integrated whole of both engineering and social concepts. This approach provides more understanding of the causes of disasters than the single-disciplinary approaches, which is necessary to come to improved risk management of complex technological systems. The concept is illustrated by analysing the Zeebrugge ferry disaster.

INTRODUCTION

Complex man-made disasters have been studied many times. Most studies are characterized by a single-discipline approach. So are the results of those studies. In this paper, an effort is made to show advantages of an interdisciplinary approach for analysing disasters involving complex technological systems. As an example, the causes of the Zeebrugge ferry disaster will be analyzed from both engineering and social science points of view. The engineering perspective includes both a quantitative risk assesment model and the design of the particular vessel. The social science approaches consider psychological and organisational aspects. All perspectives will be used to determine causes that lead to the accident. In order to get a clear view on the overall causes of this complex accident, the different perspectives have to be integrated. Useful integrative work which has been done recently is discussed. System approaches seem suitable for further integration. They will be discussed in general briefly. For the purpose of understanding the accident, Perrow's 'normal accident' concept is used. An influence diagram and a multi-level approach are proposed and appear to be very useful for our aim: structuring and explaining the variety of causes that lead to the accident. The paper ends with conclusions for risk management of complex technological systems.

entire statistics. Another problem is the risk measure used: 'total loss' does not express the number of lethalities, injured, and degree of personal damage.

Design of Ro-Ro vessels

Instability leading to capsize is generally seen as one of the major threats for passengers on a Ro-Ro vessel. Unobstructed vehicle decks imply a total lack of subdivisions above the bulkhead deck (uppermost deck up to which transverse watertight bulkheads are carried). This is the principal difference between Ro-Ro passenger ferries and conventional ferries.

Collisions, operational errors, and fire extinguishing operations can lead to large quantities of water on the decks. I.M.O. (the International Maritime Organization) Regulations on Subdivisions of Passenger Ships 1984 require little initial stability (only 0.05 m metacentric height) and very little freeboard (0.076 m) for ships in damaged condition. Applied to Ro-Ro passenger ferries it is clear that the chances of surviving in such a situation are non-existent [3]; the dynamics of the water (including waves), strong winds (possibly combined with current) or just giving rudder can all lead to a small (extra) heeling, allowing water to flow above the bulkhead deck.

The static analysis which has been used successfully for conventional passenger vessels does not apply to Ro-Ro vessels. In the latter case water is not restricted to small areas and thus allowed to run freely over the whole deck, which destabilizes the vessel enormously. Even small amounts of water on the upper decks can lead to a rapid capsize.

The 1984 Regulations did not express the fact that a Ro-Ro ship is, by its basic design, a special ship. Further, the regulations are restricted to the system 'ship'. In this paper it will be pointed out that, for assessing safety, it may be better to define the system as 'shipping'. Not fail-safety of a ship, but safety of the whole shipping system is the real issue.

APPROACHES FROM SOCIAL SCIENCES

Psychological perspective

Human-error as a cause for accidents has been studied extensively and is said to be a crucial cause in 90% of marine accidents [4]. The normative model of human decision making, which assumes a deliberate exploration of alternatives and their consequences, is not applicable to the actual behaviour of people about to be engaged in accidents. Routine behaviour is preprogrammed to such an extent that it occurs without any explicit consideration of risk (assistant bosun going to sleep, and bosun, loading officer and captain not checking whether doors are closed or not).

Recent research has shown that false hypotheses are the prevalent factor in the human-error induced accident causation process [4].

These findings are very interesting. However, relevant questions like 'Why are people diagnosing their situation incorrectly?', 'Which human-errors lead under what conditions to accidents?' and 'What determines the magnitude of the accident?' cannot be answered from a psychological perspective only.

Organisational perspective

According to Turner, events occur in the phase immediately preceding an accident that indicate differences between reality and planned reality [5]. He calls this phase the 'incubation period'. Due to rigidities in perception and beliefs, these events remain unnoticed or are wrongly interpretated.

In the case of the Herald there were many events which indicated unsafety, as is clear from the warnings given by the captains and addressed to management. However, management did not believe in the vulnerability of the ferry system and simply gave priority to low cost over increased safety. Maximizing the profits caused very tight schedules, which caused a time-pressure to such an extent that many operating breakdown of the system, what he calls a 'normal accident'. The more complex and the more tightly coupled a system is, the more unexpected and linked the events are; the more it is prone for normal accidents.

As has been noticed in the previous sections, there are many important decisions directly concerned with safety that are taken ashore by management. Further, the harbour situation causes the need for trimming the ship which is a crucial factor in the accident causation process. Therefore it makes sense to take broader system boundaries than Perrow: the system to be studied is 'Ro-Ro shipping' more than 'Ro-Ro ship Herald of Free Enterprise'. Within these new boundaries the different monodisciplinairy perspectives can be incorporated.

Procedures carried out too hastily or at sea instead of ashore, using parts of the ship differently than designed for, make the system more complex than is perceived at first sight. The trimming of the ship is necessary for loading the upper deck in other constructed berths than the berth for which the ship has been designed. Time-pressure forces captains to untrim the ship at sea because the pumps do not have by far enough capacity to empty the ballast tanks in the minutes after loading. However, the properties of a ship, including stability, do change by trimming. Captains may accelerate ships that are significantly trimmed and overloaded more quickly than normal in order to gain time back, regardless of the possible hydraulic aspects. Bow doors are used for ventilation. However, there are no indicators that tell the captain whether those doors have been closed or not after the ventilation procedure. S/he relies upon the negative checking system, which assumes everyone does his/her duty. However, crews are 24 hours on board, and officers do not always communicate explicitly when it is not required. There is much other work to be done in the many quick crossings of one of the world's busiest fairways. Meanwhile, Ro-Ro ships still have the potential for a rapid capsize.

As mistakes at sea do not have to be reported, the authorities were not fully aware of the circumstances within the system and thus not able to maintain the regulations that deal with proper safety management and good seamanship.

So the Ro-Ro ferry system can be considered as complex and coupled, not because sailing a ship itself is that complex and coupled, but because an error-inducing culture, arisen due to time-pressure and lack of external control, makes shipping more complex and coupled than technologically necessary. According to Perrow such a system is prone for normal accidents. Such an accident occurred at Zeebrugge on 6th March 1987.

Influence diagram

Influence diagramming is an easy way to describe the factors that influence safety and their (causal) relations. Nevertheless, it is very useful as the method is very effective in showing the wholeness of the system and the limitations of the ranges of monodisciplinary perspectives. Figure 1 illustrates such a diagram. The aspects that influence the safety of the Ro-Ro shipping system have been placed along the different life-cycle phases of the system until the accident occurred. Each of the monodisciplinary perspectives concentrates mainly on one phase: the psychological perspective on the daily operations, the organisational perspective on management, engineering on basic design and hardware development. The diagram shows that relevant decisions made at different times and in different phases do influence each other, and that interdisciplinarity is necessary for tuning these decisions. Unsafety appears to be an evolutionary process in which operator errors are the last stage before the accident happens. Theadvantage of seeing unsafety as an evolutionary process are: (i) safety can be improved by taking safety measures in other stages than the daily operational stage (ii) improved predictions of probability and magnitude of major accidents seem possible.

At the individual system level the most important factors are personal interests, legislation from policy level, company orders from organisational level, and working environment. The working environment can be complex due to decisions made on the organisational level (like in the case of the Herald) or on the policy level. The complexity of daily operations can lead to false hypotheses which are important causes of human-error. Further, personal interests like making a career or working pressure can force individuals to perform unsafe acts (although forbidden by legislation).

The advantage of a multi-level model is that it explicitly shows the relevance to safety of decisions at all levels. In addition, the interactions between the levels are stated. These interactions seem to explain the (un)safety of a system. Besides a better overall understanding of the causes of disasters, this approach offers the possibility to (re)design complex systems effectively by tuning the decisions made at each level.

CONCLUSIONS

Safety of complex technological systems is concerned with both engineering and social sciences. Approaches to safety of such systems made within the different disciplines provide much insights. However, risk management of the ever increasing and ever more complex large-scale systems calls for a more integrated approach. To analyze a disaster in or assess the safety of such a system, an influence diagram and a multi-level model are very useful. An influence diagram shows how unsafety of a system develops in time, and the need for interdisciplinarity for effective risk management. A multi-level model will explicitly show the trade-offs being made at each level, as well as their consequences at other levels. The discussion to what extent accidents can be anticipated remains open. But by applying appropriate approaches we know at least what underlying causes may lead to accidents, as has been illustrated with the Zeebrugge tragedy.

Further development of the integrated approaches is necessary. The economic aspect is supposed to have much influence on the safety of a system. Therefore, it should be studied more thoroughly. Other important research topics are the relations between meso and macro level. Approaches considering these relations and good multiple case study research are required for sharpening or redefining concepts, definitions, and models in order to make these models operationally useful.

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ASPECTS OF EMERGENCY MANAGEMENT IN NORWAY

AIR POLLUTION MONITORING FOR ON-LINE WARNING AND ALARM

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Abstract

The Norwegian Institute for Air Research (NILU) has been involved in the establishment of air pollution monitoring and modelling for warning and alarm systems during accidental releases and in the surroundings of industrial sites.

During the oil fires in Kuwait following the 1990-91 Gulf War, NILU was asked by the World Health Organization (WHO/UNEP) to provide and install monitoring stations for an air quality information and warning system. The installation included a data network with dedicated telephone lines connected to a surveillance centre at the Environmental Protection Department in Kuwait City. Data were transferred to the centre every 5 minutes.

On behalf of the United Nations Centre for Urgent Environmental Assistance (UNCUEA) NILU is establishing a mobile measurement platform and field laboratory for monitoring and modelling of toxic and explosive gases released after a major accident. This technology is further developed to represent part of the environmental information system (EIS) in the MEMbrain project on Major Emergency Management. The concept including on-line meteorological measurement for modelling danger zones linked to mobile gas sensors and unmanned airborne vehicle (UAV) will be presented.

1. Introduction

NILU is responsible for air quality monitoring and surveillance programmes in Norway, and represents the Central Co-ordinating Unit for the European Monitoring and Evaluation Programme (EMEP). NILU has also been involved in the establishment of air pollution monitoring and modelling for warning and alarm systems. As part of these tasks NILU has developed, established and operated air quality measurement programmes during the last 25 years.

NILU was asked by the World Health Organization (WHO) to provide and install monitoring stations for air quality in Kuwait during the oil fires following the Gulf war in 1991.

NILU is together with several co-institutes developing a complete environmental surveillance and information system (ENSIS '94) for the winter olympic games in Lillehammer.

A mobile measurement platform for monitoring, modelling, forecasting and warning during large accidents is being developed for UNCUEA. This technology will be further developed to be established as the land based environmental information system as part of the Eureka MEMbrain development project.

2. Air quality monitoring system for Kuwait

NILU was requested by the World Health Organization (WHO)/UN Environment Programme (UNEP) to provide and install monitoring stations for air quality after the Gulf war in 1991. The NILU tasks were part of the UN Inter-Agency Plan for the Gulf Region. The objectives were to combat the destruction of the environment by supporting necessary air quality information, and to inform and alarm the population of Kuwait City in case of smoke drifting into highly populated areas (Sivertsen et Berg, 1991).

NILU had also been operating air quality instruments at a Norwegian field hospital in Umm Quasr at the border between Kuwait and Iraq since mid May 1991. The installation of a monitoring

In the afternoon of 7 June 1992 the wind suddenly increased to more than 10 m/s, the temperature dropped and the PM_{10} concentration exceeded an extremely high value of 8000 µg/m³.

The UN/WHO supported installation of an air quality surveillance and warning system for Kuwait was operated at the end of the large oil fires in the area. It was not enough time and the technical facilities did not permit a complete test of the system as an operational warning system. The installations are, however, used presently in the routine surveillance of air quality in Kuwait.

3. Radioactivity alarm system for Norway

NILU has developed and installed an automatic alarm system for radioactivity in Norway, originally requested by the Ministry of Environment following the Chernobyl accident in 1986 (Berg, 1994).

A total number of 21 monitoring stations are operated all over Norway. One station is located in Russia on the Kola peninsula about 150 km east

Figure 3: The radioactivity alarm system for Norway

of the Norwegian border. Eleven stations are equipped with total gamma radiation detectors. The rest are radiation spectrometers measuring specific radioactive isotopes. Most of the spectrometers are located in the two most northern Counties of Norway, closest to the border of Russia (Berg, 1993).

The detectors are connected to a NILU data logger. Data are collected automatically and transferred via telephone lines to the NILU computer centre every 3 hour. A computer programme is performing data quality controls and is calculating and presenting radioactivity levels and spectra of nuclides.

In case the total radiation or the concentrations of specific nuclides exceeds a pre-set level, an alarm is automatically tranfered to the NILU telephone or to a personal pager carried by NILU personell. The alarm levels are set for specific isotopes like Cs-137, Cs-134 and I-131. In this way it is also possible to explain the reasons and to distinguish between potential sources for radioactive releases when an alarm is issued.

If the readings are found relevant the responsible authorities are alerted and the Norwegian Nuclear Emergency Organization and the Advisory Committee for Nuclear Accidents under the Norwegian Radiation Protection Authority will be set in operation.

The NILU alarm system is very sensitive and alarms have been issued during natural occurring "high levels". This could be washout of radon daughters during storms, or strong "leakages " from the soil of similar isotopes. The spectres enable us to distinguish between "new accidents" and radon daughters, and have improved the validity of the warning system

The NILU established warning system is operated in close co-operation with the other Nordic countries, which make the system even more reliable. The experience so far is a fast response reliable warning system with a very high degree of data availability.

et al., 1993). As part of the input to the models a chemical library will be installed.

The container also include radioactivity sensors to measure total radiation levels and the level of specific nuclides.

The NILU staff participated together with the Norwegian Pollution Control Authorities and UNCUEA in Geneva in an exercise to test the communication system. A hypothetical gas tank accident in Algeria was followed and evaluated throughout 24 hours. The cloud composition and size were estimated and information and warnings were issued.

5. MEMbrain

A further development of the land based environmental information system is undertaken as part of the Eureka project MEMbrain. NILU is basing this development upon the existing experience from the work performed in the radioactive alarm system and in UNCUEA (Sivertsen, 1993).

New technologies and knowledge gained through the establishment of a complete Environmental Surveillance and Information System (ENSIS '94) developed for the Winter Olympic Games in Lillehammer, will also be used in the MEMbrain project.

The development of the land based alert and emergency system for MEMbrain will consist of three parts:

1. A measurement platform with chemical sensors, instruments for measurements of radioactivity, meteorological equipment, data transfer and storage systems and dispersion modelling capability for accidental releases and normal dispersion conditions.

2. Development and testing of dispersion models for accidental releases, transport and dispersion of gases and the consequence analysis in local scale. Routines for quality control, user interface and geographical information systems for presentation of results will be included in the development.

3. Preparing the existing radioactivity data for use in the Norwegian MEMbrain case, including demonstration of models for estimates of radioactivity on a local scale.

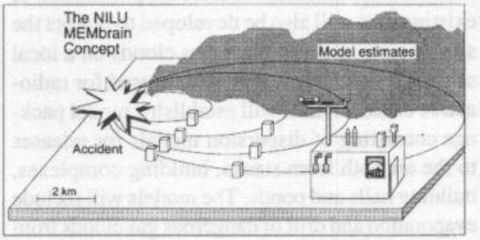

Figure 5: The MEMbrain land based environmental information system

In addition the possibilities for use of unmanned airborne vehicles (UAV) will be evaluated and reported, particularly for use in major accidents.

5.1 Measurements platforms and field laboratory

A measurement platform for mapping of the danger areas after accidents of all kinds is being developed. This platform will be equipped with mobile sampling units that can be used for mapping the gas clouds close to the accident point to submit information about the releases; release size, release type, amount and composition of the gases in question. Together with meteorological data this information will represent the input data for estimates of transport, dispersion and the size of chemical clouds following the accident. This will represent the basis for forecasting and reporting of danger areas. The meteorological data available on the platform will be used on-line as input to the models, through evaluation of appropriate scaling parameters (Gryning et al. 1987).

Equipment for tracer gas experiments can also be installed in the platform. This technique can be used for detailed mapping of leakage and dispersion patterns if required.

Integrated User Interface for MEM Decision Support

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ABSTRACT

Decision support systems for Major Emergency Management (MEM) must provide efficient information collection, processing and presentation for a variety of accident scenarios and for end users with different backgrounds. Regardless of changing conditions during an accident, the MEM decision support system should give a consistent and dependable presentation of relevant information that can be adapted to the situation at hand.
The design of user interface for Major Emergency Management systems must reflect the needs of the end users and enhance their ability to extract information, combine data from different sources and present a comprehensive picture of the situation at all stages in accident progression. To do this successfully, there must be a systematic and structured approach to user interface design, encompassing information hierarchy, navigation principles, display design and the communication between operator and MEM system. In a MEM situation the operations centre has to cope with an avalanche of messages, requests and commands, it is the task of the user interface to provide the means for compiling and presenting an ordered overview of this complex situation.

1. INTRODUCTION

The aim of Major Emergency Management (MEM) systems is to support the emergency organisations in their efforts to protect the public and the environment. An efficient MEM system can become a decisive factor in time critical situations, provided it measures up to the demands emergency organisations have to reliable information collection, communication and information presentation. It is very much a question of structured information flow, not only within the MEM system itself but, equally important, between the MEM system and the user.

It is the latter which will be the focus of this paper. Given that a comprehensive software and hardware system has been established containing all information needed for handling a major accident, it becomes a question of how to make it accessible to the decision makers. That translates into a demand that the end user must be given the means for extracting the information he or she needs, combining it to suit the task at hand and then present the best possible overview of the situation as basis for decision. The user interface of a MEM system shall be able to fulfill these requirements for a variety of accident situations, and in addition cater to the needs of decision makers with quite different backgrounds and responsibilities.

To establish principles for MEM interface design one should first try to identify all common factors in accident handling, regardless of the type of event. The basic functions to be fulfilled by the MEM system are all motivated by the desire to establish the best possible basis for correct decisions. The first step in providing an ordered transfer of information from sensor to decision maker is to establish principles for user interface design. A structured interface design process is a prerequisite for an efficient transfer of information to the end user.

2. MEM SCENARIOS AND INFORMATION NEEDS

Hopefully a major emergency will be a rather shortlived affair, and generally one would tailor a MEM system to support short term emergency management, meaning the time from the initiating event until the threat to the public is reduced to an acceptable level. But for many scenarios one can actually not draw a clear dividing line where accident mangement ends and the handling of the aftermath begins. An explosion or an aircrash requires intense but generally short periods of MEM system activation, and the system, including the interface, has to be designed for adaption to such situations. But there are other emergencies which have a quite different time evolution and may require situation monitoring and initiation of measures over a prolonged period. Examples are spread of dangerous chemicals and radioactive materials, such as happened in the course of the Chernobyl disaster. In the immediate vicinity of the power plant it was necessary to implement drastic measures, from the firefighting immediately following the explosion to the evacuation of tens of thousands in the first days, thereafter long term actions with relocation of even larger population groups. Although the Chernobyl scenario may remain the only one of its kind, the MEM system shall in principle be designed to handle emergencies of a very wide class. This has an impact on the design of the user interface, and one should be aware of the demands placed on system information processing under changing circumstances.

In short term accident handling one has to concentrate on time critical events, and preparation and forethought saves precious time when an accident situation arises. The question is actually how one should prepare for the unexpected, and that is generally difficult. But there are some principles that can be applied which may provide the user with the right information at the right time. To do that one has to figure out on beforehand what are the expected information needs and structure the user interface accordingly. One way of doing this is to make the user interface, or part of it, function oriented. This is appropriate for the user which requires information to perform a specific function or task. Another possibility is to use scenario based structuring with the user interface tailored to the information needs as the accident scenario evolves. In many cases, particularly for handling of large accidents, it may be advantageous to use a combination of the two approaches as there will be persons assigned to cover part tasks concurrently with the coordinated handling of the different accident stages.

In Norway a MEM system for assisting the nuclear preparedness organisation in handling nuclear emergencies is being developed [1]. The user interface design principles being described in this paper will be applied for this Norwegian MEM system.

3. BASIS FOR USER INTERFACE DESIGN

Since MEM systems are often developed as a combination of several free standing tools, the integrational aspects of the user interface becomes even more important than in normal system development. The overall goal must always be that the user should interpret the system as one and not as several systems arbitrarily put together. This integration feeling can be achieved by establishing communication facilities "behind the scene", allowing different tools to freely communicate. However, from the user's point of view the most important integration work should be concentrated on the user interface itself, both with respect to presentation and interaction.

When designing a user interface there are some crucial questions which have to be answered on beforehand [2]. Typically, questions like

- how many screens will be available for operation ?
- how many users will access the system in parallell ?
- can certain information be tied to specific screens ?
- does one allow the system to create new displays on-line ?

are important to clarify. However, since MEM systems normally will operate in many different environments, from simple one screen PC systems to multi-screen computer network solutions, flexibility of the user interface is one keyword. One also has to keep in mind that one MEM system can be operated upon from different sites, typically one may have an operations centre with a high resolution multi-screen setup, while personnel at the emergency site may have low resolution hand-held devices for communication with the operations centre. This means that presentation of information must be made in such a way that the utilisation level become optimal for all users.

3.1 Structuring of the Information Displays

The structuring of the user interface is perhaps the most important item for the user. When he/she is to make use of the system, a natural information structure is a major factor for optimal utilisation. One way of structuring the user interface in a MEM system is to divide the interface into several information layers, typically

- entry level displays
- information overview displays
- medium level displays
- low level detailed information displays.

These displays are of a typical hierarchical nature and the user must have an easy way to navigate within this information hierarchy. The structuring of the medium and low level displays must be done in such a way that it is logical for the user. The structure could be functional based or scenario based, in many cases one would choose a combination of the two.

3.1.1 Functionally based Structuring

Functionally based structuring means that displays are tied together on a functional basis and that display groups are built up of pictures with logically coherent information content. In this way the user can navigate within a functional subsystem of displays for addressing information belonging to one logical area.

3.1.2 Scenario based Structuring

A scenario based information structure is based upon the natural development sequence of an emergency. The information is structured so that the user can address display groups describing each stage of a development of the emergency. A scenario based information structure, related to the Norwegian MEM application, is illustrated in figure 1.

Accident progression phases →	Event	Impact (site/vicinity)	Impact (distance)	Source control	Final stage
	Emerg. org. (alert)	Situation assessment	Predicted effects	Consequences, mitigation	Final assessment, rehabilitation
System functions	Source info. (library)	Severity (site info.)	Dispersion (calculation, meas.)	Model vs. measurements	Known /pred. effects
	Meteorology (library, dynamic)	Contamination (library/pred.)	Contamination (pred./measured)	Contamination monitoring	Overview, measured contamination

Figure 1: Scenario based information structure

3.1.3 Navigation Aspects

Navigation between the different information levels, and inbetween displays at the same level, should be made as self-explanatory as possible. The following guidelines are suggested :

- any picture should be accessible without numerous selections in the hierarchy
- softkeys may be used for frequent operations (e.g. return to top level picture, return to previous picture etc.)
- there must be a consistent approach for sideways navigation in the hierarchy
- operation of windows (re-scaling, moving within the screen, closing, iconising etc.) should be made using standard window handling, for instance MOTIF
- the use of icons should be possible, however, it should be carefully considered what to do with icons when the user is moving within the information hierarchy.

The possibility for creation of an overloaded screen exists and it should be considered whether to perform automatic system cleanup in certain situations. However, non-user started operations must only be performed with great care.

3.2 Information Presentation.

The presentation of information on the screen should be made in an uniform way throughout the application. The same type of information should always pop up at the same place on the screen. It is common to organise pictures in fixed and temporary fields :

- fixed fields (e.g. picture field, dialogue field, message field) and fields for common information has always the same relative placement on the screen whenever shown (refer figure 2)

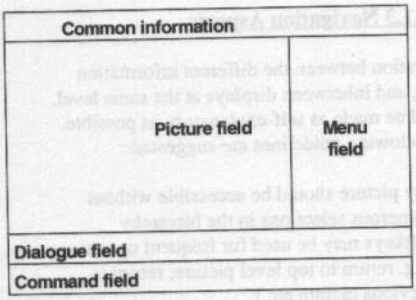

Figure 2. Placement of fields on the screen

- the information within the picutre field is the different main information types of the application (e.g. geographical information)
- the information in the fixed fields (e.g. lead text) accords with the main information within the picture field, similar content has same relative placement within fields
- the size of fixed fields as dialogue and message fields is according to the information content
- temporary fields (windows) are shown and deleted on request by the user
- temporary fields can either be shown initially in a fixed positiion within the screen or according to default criteria for how or from where they are requested (e.g. when a window is requested by addressing within a map the window should not overlay the addressing point)
- temporary fields may also be placed at specific positions requested by the user
- the information in temporary fields is strictly context sensitive

The density of information is dependant upon different criteria, but some guidelines may be given:

- the information density should be chosen according to how well known the picture is to the user (how often is it used)
- in pictures well known to the user the information density is only limited by the need for visual separation, however, consistency in information placement is required
- in pictures seldom used one should be more restrictive with loading much information into the pictures

Experience from industrial applications clearly shows that high information density is preferable to frequent need for picture changes. It is important to design the user interface in such a way that work operations and the request for specific information requires a minimum of picture changes.

3.2.1 The use of Colours

The use of colours is an important factor in information systems, since colours can be used for enhancing the user's perception of the system [3]. However, wrong use of colours may greatly reduce the information content of pictures and hence reduce the system's overall effect. The following can give some ideas on how to use colours in the most efficient way :

- combination of colours, e.g. foreground/background colours on the screen, should be chosen according to visual laws for contrast colours and coloured light
- the use of colours must be uniform and consistent, i.e. one colour must only have one meaning in a specific context

- alarms and warnings should have carefully selected colours, these are not to be used for any other purpose
- especially important information within pictures may be given high intensity colours, less important information could be displayed in low intensity colours
- the use of colours in combination with symbols should be carefully considered, bright colours and big symbols may give an unintended dominance

3.2.2 The use of Symbols.

The human brain perceives much easier symbols and graphics than loads of textual information. Symbols should be used when they will ease the user's perception of the information being presented. Some general guidelines for use of symbols in information presentation :

- use of symbols must be uniform and consistent, i.e. one dedicated symbol shall have only one meaning
- graphic symbols should, to the extent possible, be selected from national or international standards
- symbols illustrating specific installations or components should have a profile resembling the physical reference
- the size of symbols must be adjusted to their context
- relative symbol size need not reflect physical size of installation or component
- symbols may have dynamic statuses associated (e.g. different shape or colour whether or not the installation is in operation or not)
- all information related to symbols must be shown at fixed places relative to the symbol

3.3 Automatic Picture Generation.

An important way of presenting the most relevant information to the user at any time would be to let the MEM decision support system provide basic functions for presenting and structuring information on-line. This means that the system itself will have possibilities for re-structuring pictures, as well as generating new pictures, which the system "feels" will provide the user with valuable information [4].

However, such automatic re-arranging of pictures or generation of new pictures should be performed with great care, since it may confuse the user more than assisting him/her. Especially if the user is addressing specific pictures to gain information and the system has re-arranged them, it will mainly be irritating to the user. In most cases the system re-arrangement of pictures should be possibly only on a limited number of specific pictures, of which the user is aware. In such cases automatic generation of pictures with the most relevant information can give a considerable effect of the user's understanding of the situation he/she is to supervise and control.

3.4 User Alerting

When supervisory tasks are included in the MEM system, e.g. measurements of air or water contamination, a valuable addition to the system could be to include some on-line limit checking of measurements. Such checking would result in alarms when certain limits are exceeded. These alarms would be of great interest to the user and should be presented to him/her as soon as they are detected. The alerting mechanism could be solved in different ways. One possibility is to use a dedicated alarm screen, showing all relevant alarms at any time. Another way could be to make an alert on the user's screen, e.g as a blinking icon in one of the screen's corners, no matter in what context the user is working.

4. MAN-MACHINE COMMUNICATION

Man-machine communication describes how the user is interacting with the computer, e.g. choosing what to be presented and , partly, how it is to be presented. This communication takes place through dialogues, where the user requests information and the computer supplies information. Proposed criteria for dialogues are :

- a given command/menu choice/symbol adressing must always be responded, the user should never wonder whether or not his/her action has been accepted or rejected
- faulty user action should not be accepted by the system
- if a command consists of several parts, only the faulty part should have to be repeated
- the user should have the possibility of changing any parameter of a multi-parameter based command
- a regret/undo function should be available and command confirmation should be considered
- one pointing device should be selected (e.g. mouse, trackerball, light pen)
- all messages from the system should pop up in the fixed message field

In applications with a multi-screen setup, the system must be able to handle simultaneous communication from several screens. This may imply that the same dialogue can take place from several screens. It is important that users can work independently at their own screen no matter what is happening on the other screens.

5. GEOGRAPHICAL INFORMATION SYSTEMS

Most MEM applications , including nuclear emergency MEMs, [5] will as a major part of their user interface include a Geographical Information System (GIS). It is mandatory that in those applications where the user interface encompasses a combination of a GIS and other user interface builders, the user should see an integrated approach when operating the system. This means that the GIS has to adapt to the following demands :

- the display within the screen must be adjustable to cope with the overall screen layout definition
- it must be able to meet the selected ways of addressing
- the use of menus must conform with selected standards (e.g. MOTIF) or the GIS should be able to utilise external menu systems
- it must be able to share the screen with other applications, either as windows or in a split screen environment
- since the total requirements to the user interface most probably is not met by a GIS alone, it must be able to communicate and possibly act as a subordinate to other systems

6. TOOL CONFORMANCE TO USER INTERFACE LAYOUT AND DESIGN

To present the appearance of an integrated system it is of major importance that all tools conform to the same principles for information presentation. That is, they should

- conform to the chosen style guide
- use standardised graphical symbols
- use standardised colours
- use the same man-machine communication principles.

These restrictions put definite requirements to all tools which are supposed to be a combined part of an integrated MEM. The user interface handling of such tools must be done in a flexible way to allow for definite adjustments, which may become necessary in specific applications. To achieve optimum flexibility all tools aiming for MEM integration should have a very loose coupling to the user interface management, allowing for easy adaption to the chosen User Interface Management System (UIMS) and the chosen way of presenting information [6].

7. FUTURE EXTENSIONS OF MEM SYSTEMS

A MEM system is basically intended for use during a major accident, where there is a pronounced need for handling a complex information and message flow, and resource utilization and actions have to be coordinated. However, having constructed the foundation for a MEM system one has also generated a framework

for computer based systems of a much larger class. Among these are general surveillance and monitoring systems for rescue organisations, police and civil defence, large transport networks and resource distribution in general. Basic requirements common to all are knowledge of or means for: Resource information (data storage), resource distribution (GIS), communication (internal and external), coordination (operations centre), control (control station).
The user interface, although concentrated in the operations centre, plays an essential part in all these functions and determines to a large extent the efficiency of the system as a whole.

The demands that MEM systems put on user interface can be fulfilled by an integrated UIMS - GIS combination. But there are certain functions that may not be generally available or has to be improved in future MEM systems. One particular function is automatic tracking of moving objects and plotting of position. This is a standard facility in military command centrals, and there is probably much to be learned in MEM system development from military systems. The problem is usually how to gain access to such information and make it available for commercial utilisation.

For handling of nuclear emergencies ther exist systems at different stages of completion in many countries. Although they tend to be notion or plant specific they offer valuable input to the structuring of support systems aimed at accident scenarios affecting several nations.

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THE USE OF RISK ANALYSIS IN CONTINGENCY PLANNING

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Abstract

The main functionalities of the Public Protection System (PPS) and Chemical and Radioactive Information System (CARIS) which are being developed in the European Eureka project MEMbrain will be described. PPS is a management decision support system that will serve several objectives, related to planning, training and real emergencies. Reliability theory and risk analysis should, in principle, be extremely important disciplines for emergency management to use and learn from, although they will never replace experiences from real life accident handling. However, the exchange of ideas between the theoretical field of reliability and risk analysis and practical emergency management is rather limited, and far from what it could be for the benefit of both sides. Some of the reasons why it is so are described, and remedies discussed. Finally, one way risk analysis could be done, and presented, for emergency management in a MEMbrain/PPS context is outlined.

1. Introduction

The European Eureka project MEMbrain /1/ are in the process of developing a computer based emergency management decision support system. The MEMbrain project includes different participating countries which shall develop national applications, all based on a common MEMbrain technological platform. The common platform shall contain modules that may be tailored to a given application in a much more cost efficient way compared to the case if each country should develop their own applications from 'scratch'. In general, the functionalities of the MEMbrain platform shall be able to:

- monitor hazards during nominal situations
- support contingency planning
- train emergency management and personnel
- display accident exposed areas on computerised maps
- support emergency management's decision making
- provide communication facilities to those involved in an emergency

The national applications range from man-made to natural disasters; from nuclear and chemical accidents to flooding and earth quakes.

2. The PPS and CARIS modules of MEMbrain

QUASAR's responsibility in the MEMbrain project is concerned with two work packages, the PPS (Public Protection System) and the CARIS (Chemical And Radioactive Information System). The PPS shall give advice on how best to protect people (public and rescue personnel) from the effects of an accident, e.g. how to avoid or reduce hazard exposure, or how to effectively evacuate an area. CARIS shall provide rapid access to information on hazardous materials (chemicals, radioactivity) and their properties related to flammability, solubility, dispersability, toxicity, etc. and the associated needs for protection and health consequences of different degrees of exposure. CARIS shall also provide source term information, which through dispersion calculations (another MEMbrain work package), will provide input to PPS. CARIS (together with other MEMbrain modules) will also be used on a daily basis in the surveillance and monitoring of hazard sources in an area. In this way, the operators will enhance and maintain their skills by applying the MEMbrain system for normal working day tasks. This will alleviate, but not eliminate, the need for training and emergency exercises.

In a real emergency situation, or in a simulated case for training purposes, accident information shall be presented on a digitised (computerised) map, based on a Geographical Information System (GIS) technology. Different GIS layers may then be used to represent information that are essential to emergency management, such as:

- The area of a toxic or flammable gas dispersed cloud, radiation levels, explosion impact zones, etc. - as reported, as monitored by remote sensing devices, or as simulated to predict a future status.
- The location of people to be assisted or rescued, in particular those with movement disabilities or other needs which require special assistance.
- The location of rescue means and protective equipment, as well as their availability and response times.
- Finally, storage tanks for chemicals, pipelines and other sources of hazard may also be displayed, information that are essential in the evaluation of possible, further accident development and in the selection of escape routes and evacuee destinations.

Information that are not GIS based, like databases over hazardous materials (chemicals, radioactivity, etc.) and their effects on life and environment, as well as knowledge concerning protection against these hazards will also be available from the PPS/CARIS system, either in a separate window or on another screen.

The PPS and CARIS modules will thus give emergency management and rescue personnel an immediate overview of the situation, as it is - and as it is likely to develop, and what the potential hazardous consequences might be.

3. Risk analysis - possibilities and limitations

Information related to the reliability and risk levels associated with systems is of high importance to emergency management. A 'system' may be a single chemical plant or a defined geographical region containing several sources of hazard. Reliability and risk analysis are dedicated to provide risk related information and are gaining in strength and acceptance by the scientific community as well as by (the high risk) industry. Such analyses are often called Probabilistic Risk Analysis (PRA) to emphasise the probabilistic or stochastic nature of the phenomena studied. PRA as a discipline is only a few decades old /2/ and is said to be the fastest growing profession beside the computer and environmental technologies. It started with the aim to improve the reliability of weapon systems during World War II. During the fifties and sixties, the type of consequences studied have been extended to also include safety and health (e.g. fatalities, casualties, injuries), and the term risk analysis was coined. The application areas of PRA's have gradually increased in number, and such studies are now used to:

- verify compliance to reliability, availability and safety criteria both during design and operations
- drive the design process
- provide input to preventive safety work
- assist in contingency planning
- provide information and support decisions during emergency operations

The order in which the list above is presented also reflects the extent to which PRA's have actually been adopted and used by society. An established practise in the Norwegian offshore oil sector is that the authorities require risk analyses to be conducted at different stages in the development of an oil field as part of the verification and approval process. PRA's have also increasingly been used by industry to improve design safety during the engineering phase. In recent years, PRA's conducted during the operational phase of an oil field have been used to improve the ongoing safety work. However, the use of methodologies and results of PRA in the preparation of emergency plans, or to support emergency management decisions, are the exception rather than the rule. One of the exceptions are related to the offshore safety regulations for the Norwegian Continental Shelf where findings from risk analyses may trigger specific contingency related actions required by the Norwegian Petroleum Directorate.

In principle, PRA methodology should be of great benefit to contingency planning, training and operations: Identification of hazardous conditions, how they may get out of control, as well as the effects upon people involved, are all elements which are treated in a PRA. So why are PRA's not used more frequently in contingency preparedness planning?

An answer may be that a PRA is conducted in a rather sophisticated way, and uses mathematics which many are unfamiliar with. In the modelling, Fault Tree Analysis (FTA) and Reliability block diagrams are often used. An FTA is used to analyse the causes of a hazardous event in such a way that a probabilistic calculation can be correctly performed. An outside observer would probably state that it was the concern of probability theory and mathematical convenience that have driven the development of FTA; the needs of those engaged in practical safety and emergency preparedness work were of less concern.

However, it is not the quantitative nature of PRA that is most important, although knowing the importance of accident causes is useful when mitigative actions are to be selected. Potential hazardous conditions and events that may trigger an accident - and what may make the situation better or worse - are of much more interest than the quantitative results as such.

Another reason for the lack of use of PRA's is related to the way accident causes and propagation of undesirable events are identified. The FTA model does not represent the dynamic nature of an accident development. FTA is a purely logical representation of the causes that may lead to a dangerous situation, developed from a global to a detailed view, or in a top-down approach. An FTA is thus a suitable instrument to detail causes until a level is reached where failure rates and repair times (quantitative data) may be identified and assigned to (basic) events. The procedure is such that one has to backtrace, starting from the effect (a dangerous event like e.g. gas leakage or tank rupture), and then identify possible causes. The starting point of the FTA, the dangerous situation (also called the top event) is then the starting point for the other main tool of PRA: the consequence or event tree analysis. The event tree is generated in the opposite fashion in comparison to the fault tree: by working in a forward time direction.

The consequence analysis is normally represented by a binary tree, where the edges are related to events significant for the accident to develop. An example may be useful at this point: if the top event is a Propane tank rupture, the first node may be represented by the question "immediately ignition?". From this point forward, two scenarios emerge. Then, for the 'unignited branch', the next significant event may be related to the possibility of a delayed ignition, and another two scenarios are created. This continues until all branching possibilities are exhausted. The event tree analysis can represent the dynamic aspect in that the sequence of events is essential to describe the accident tree scenarios, but it lags behind on the logical aspects compared to the FTA. For this reason, 'small' fault tree models are sometimes used to determine the branching probabilities of a consequence tree. However, this difference in how FTA and event trees are generated, and the fact that they must be interpreted differently, is confusing for outsiders. This leads to difficulties in understanding and using PRA results.

One rather serious deficiency of PRA is the lack of representation of problems related to operations, repair and maintenance tasks. Human Reliability, although considered as an area of high importance, is rarely given adequate treatment. Failure events related to such issues are often not considered at all, a fact that is rather peculiar as statistics show that a large majority of accidents are (partially) caused by human errors. And if human reliability is considered in a PRA, it is often treated in a rather superfluous way. A prominent example of this is when reliability engineers use the same approach in the modelling of man-machine redundancy as they use to model hardware redundancy /3/.

Finally, the (proper) identification of risk reducing measures, and the implementation of such measures will in general require a degree of experience beyond what the risk analysts are likely to posess. Unfortunately, risk analysts normally do not have experience in neither engineering design nor in operations and maintenance, as they usually are highly specialised statisticians or reliability engineers. If the practical 'touch' is lacking, it is understandable that result oriented safety and contingency personnel are sceptical to PRA's. Consequently, PRA's are not used to the extent that they could, or rather should be.

4. Improvements needed

Although there are a lot of aspects that should be improved, as indicated in the overview presented above, the focus here will be put on how traditional PRA methods should be simplified. One primary area of improvement is rather obvious: The propagation of events leading to an accident should be described in such a way that it can easily be understood by people from other professions. In other words, the fault tree - event tree approach should be abandoned in favour of a more direct, cause-consequence way of describing the events leading to an accident.

It is interesting to note that the analytical method preferred by most designers is FMEA (Failure Modes and Effects Analysis). In FMEA, the ways each component of a system may fail are identified, and the system consequences of the different failure modes evaluated. FMEA is directly related to the hardware parts of a system, i.e. to the very same components the design engineers are familiar with. An FMEA is thus a straight forward, cause-consequence based description, representing the sequence of failure events in an intuitive way. While fault tree analysis is conducted in a top down fashion, FMEA is a bottom up approach, where one starts from each possible way the component can fail, and then follows the consequences until the system is effected - or not affected. FMEA thus lends itself to a natural way of describing the propagation of events leading to an accident, but it is not very well suited to identify undesirable events which need two or more simultaneous causes to occur.

An FTA is, however, much better suited to represent combinations of causes than the FMEA approach. And as everyone knows, it is the unexpected combination of events that leads to the most serious accidents.

An initiative undertaken by the European Space Agency (ESA) to investigate the use of hazard and risk analysis in the design process, came up with an alternative that may combine the strengths of the FMEA and the FTA. The following 'Hazard Analysis Logic' /4/ may illustrate this:

The presence of	**Hazards**
in the	**system design, operation and environment**
is manifested in	**Hazardous Conditions**
which, dependent upon	**Initiator Events**
can cause	**Undesirable Events**
that combined with the	**Exposure Situation**
result in the	**Hazardous Consequence**

The ESA approach has been tested out on design reviews where safety engineers used this method to communicate safety problems to design engineers with considerable success. The main reason for the favourable reception of the method is probably related to its intuitive nature: it manages to combine a logical approach with the dynamic characteristics of accident propagation in a way that is both easy to understand and easy to apply.

5. Risk Analysis and MEMbrain

In MEMbrain, Risk Analysis will be used for at least three different purposes:

1. Evaluate a region to see if there is a need for a MEMbrain system
2. Generate scenario libraries to be used for contingency planning and training
3. Forecast probable scenario developments during an accident - partly based on scenarios from the library

For the first purpose, traditional PRA will be sufficient. But for the latter two cases, there is a definite need for an improved PRA along the lines discussed above.

The ESA Hazard Analysis Logics seems to be a suitable approach to structure the scenario descriptions to be used in the PPS module of MEMbrain. Several steps may be needed to form a complete description of the undesirable event path before an exposure situation occurs. Each step will then be the point where the scenario splits into two (or more) branches, like in the event tree descriptions. And one or more events or conditions may determine the probability of the alternative directions. In this way, the description will combine the sequential and the (Boolean) logical approach without separating the two as in the Fault Tree/Event Tree dichotomy.

To be of any use to emergency management, for planning purposes or in actual operations, the scenarios must be derived from a common starting condition. A set of scenarios, or a hazard tree, starts from the same hazardous condition, but results in different consequences depending on other events or conditions that happen along the accident path. In the MEMbrain/PPS context, the common starting condition compares to the onset of an accident, e.g. a rupture of a Propane tank. Now, if this situation has been analysed and translated to a hazard tree, the emergency management can display the tree and replay the future events of importance to investigate what may happen next, and what the probabilities are for the different alternatives. The information related to the events and conditions that may alter the direction of the accident path is of high importance to the accident fighting itself. Some of these events may be influenced by actions initiated by the emergency management, and the decision module in PPS will then be able to advice on action priorities, and what the effects on future options are. When a critical event proves true or false, meaning that it either happens or it does not happen, the hazard tree is simply updated.

This benefits of risk analysis, or rather hazard analysis, as described above, are evident when the time period from accident onset to the final consequences occur is sufficiently long. The approach may not be that suitable for rapidly developing accidents, although other MEMbrain properties related to e.g. availability and response times for rescue equipment may prove useful.

But for those accidents which develop more gradually and which can be influenced, a better use of risk analysis methods will be benficial. To achieve this, it is necessary to identify and analyse the hazardous conditions, using e.g. the scenario based approach described above, and to store the hazard trees in a database so that they can be immediately available to emergency management should an accident occur.

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ADVANCED TECHNOLOGY FOR EMERGENCY MANAGEMENT

U.S. BUREAU OF MINES TECHNOLOGY APPLICABLE TO DISASTER RESPONSE, URBAN SEARCH AND RESCUE

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ABSTRACT

Since 1910, the U.S. Bureau of Mines (USBM) has investigated practical ways of dealing with the consequences of major fires and explosions in underground mines. The results of this research have had a significant positive impact on the mining community by enhancing mine workers' chances of surviving an underground mine disaster.

Today, the Bureau continues to conduct research in mine disaster mitigation. Much of this work has direct application to search and rescue situations, such as: emergency evacuation through smoke-filled or otherwise unbreathable atmospheres, locating and rescuing survivors from rubble piles, and fire fighting in confined spaces.

Three USBM research areas are discussed:

(1) Life Support -- This effort is directed toward research into and development of closed-circuit breathing apparatus for use in hazardous environments which are likely to be encountered in the aftermath of a mine disaster.

(2) Trapped Miner Location -- A mine disaster may result in the entrapment of miners whose normal escape routes are cut-off. This research activity resulted in the development of transportable seismic technology that can be used to locate trapped miners.

(3) Mine Fire Diagnostics -- This research involves developing practical techniques for remotely monitoring how the atmosphere inside a mine changes during a fire, in order to estimate the spread and severity of an underground fire. This information is critical in deciding how best to fight a mine fire, or whether it is safe to mount a rescue and recovery mission.

INTRODUCTION

At the turn of the century, mine disasters were a commonplace event. It was not unusual for hundreds of lives to be lost in a single instant when an explosion erupted in a mine. The carnage reached such a level that congress established the USBM with the intent to improve technology and give the mining industry the means to provide a safer work place.

In the years that have passed since then, the mining industry assisted, by the USBM, the Mine Safety and Health Administration (MSHA), and other Federal and State agencies, has greatly improved its safety record. The overall accident rates for mining have greatly decline, and fires and explosions no longer account for the majority of work related deaths. Although the frequency of explosions has diminished to nearly zero, they still occur. It is against these occurrences that the USBM performs research into post-disaster technologies.

LIFE SUPPORT

In a mine fire or explosion, the mine

atmosphere can quickly become unbreathable. Along with smoke, there will be carbon monoxide and the possibility of toxic byproducts from other burning materials. Depending on ventilation conditions, the atmosphere may also become deficient in oxygen.

To protect escaping miners, Federal mining law (Title 30 CFR, part 75.1714) requires that every person that enters an underground coal mine be supplied with a Self-Contained, Self-Rescuer (SCSR). An SCSR is an emergency breathing apparatus designed specifically for the purpose of mine escape. The law also calls for these SCSR's to meet certain minimum requirements in order to be approved for use. Among these requirements it is specified that the SCSR be able to provide at least a 60-minute supply of oxygen (O_2). The National Institute for Occupational Safety and Health (NIOSH) and MSHA act jointly in providing certification for SCSR's.

Description of the Basic Technology

Part of the USBM effort in life support is to lead the drive for improved SCSR technology. By working cooperatively with manufacturers, the Bureau was able in 1989 to introduce second-generation SCSR's to the mining industry. Second-generation SCSR's are both smaller and lighter than the first-generation SCSR's that they are replacing, but are still able to meet the same performance criteria.

The main advantage derived from this improvement comes in deployment. The previous SCSR's were too large to carry and had to be stored in the mine near the locations at which people regularly work. One disadvantage of this deployment scheme in an emergency is the delay in escaping while an individual travels to a storage location to look for an SCSR. Since second generation SCSR's are person-wearable, miners can begin their escape immediately.

All second generation 1-hr SCSR's approved for use at this writing employ mainly potassium superoxide (KO_2), a solid, as the oxygen source and as a carbon dioxide (CO_2) absorbent.

Figure 1 is an engineering drawing of a chemical oxygen SCSR. One significant feature is that SCSR's deliver a breathable atmosphere through a mouthpiece, rather than a mask or face piece. A mouthpiece combined with nose clips provide a high degree of user protection without the penalty of custom fitting.

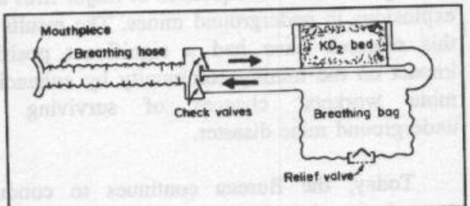

Figure 1.--Typical Chemical O_2 SCSR

Three of the four manufacturers who held current certifications for their original SCSR's have designed and gained approval for second-generation SCSR's. All three of these are chemical oxygen units. These devices are smaller and lighter than the ones they replaced. The sizes and weights of these devices, compared to their first-generation counterparts, are given in Table 1.

Although SCSR's were specifically designed for mine escape, they can also be used for escape or evacuation in other hazardous situations, such as a chemical plant fire or tunnel fire. Compared to other closed-circuit breathing apparatus intended for emergency use, SCSR's have a number of advantages: small size and weight, low maintenance, long service life, easy and quick donning, no custom fitting, and relatively low deployment costs.

Table 1.--Size and Weight Comparison of First- and Second-Generation SCSR's

	Weight (kg)	Size (L)
Draeger		
1st OXY-SR 60B	3.8	8.2
2nd OXY K plus	2.8	5.7
MSA		
1st 60-min SCSR	4.0	7.3
2nd Portal-Pack	2.4	3.7
CSE		
1st AU9-A1	4.4	6.3
2nd SR-100	2.5	3.2

TRAPPED MINER LOCATION

In some cases escape may be impossible due to injuries or damage to the mine. The only alternative may be to seek out the safest place possible, wait, and hope for rescue.

In such a situation, time is of the essence. The toxic gases from a fire or explosion will often eventually migrate throughout the entire mine. Experience has shown that unless rescue is accomplished in a matter of hours, the trapped miners will likely perish. Therefore, the key to successful rescue is to verify that some miners have survived, and to determine their location. With such knowledge, rescue teams can focus their efforts more efficiently, and the likelihood of successful rescue is enhanced.

In 1970, the National Academy of Engineers recommended that a seismic system be built and tested as a means of detecting and locating trapped miners. Via contracts and in-house efforts, the Bureau developed such a system, which is shown in Figure 2. It consists of an array of geophones, arranged in subarrays, deployed on the surface of a mine, approximately above the disaster site. The location of the subarrays must be accurately sited by surveying. These geophones are designed to detect seismic signals generated by underground trapped miners. Signals detected by the subarrays are transmitted by wireline or radio link to a seismic instrumentation truck that contains computers, recorders, CRT displays, and other equipment. The truck can be driven or airlifted to disaster sites. For the seismic system to be effective, trapped miners must be trained to respond in a certain manner. This training can be provided by MSHA or company safety instructors. As an aid and reminder, a sticker that summarizes this training can be affixed to the inside of hardhats.

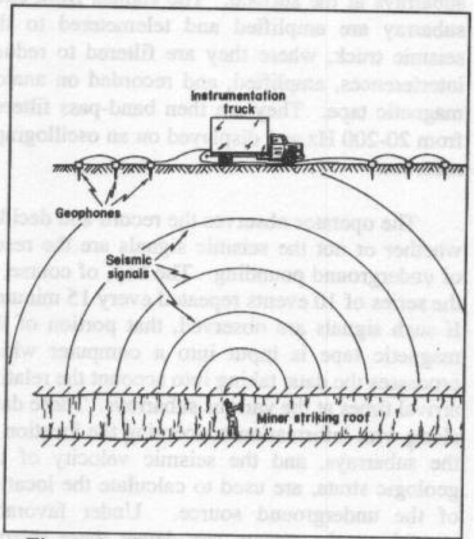

Figure 2.--Trapped miner seismic detection system.

Initially, the trapped miners should take action to improve their chances of survival. This includes keeping calm, gathering food and water, and possibly barricading to provide some degree of protection from toxic gas. Miners must also recognize that it may take hours (perhaps days) for the seismic system to arrive on the surface and be deployed. Therefore, it is important that they conserve strength, resources, and hope until then.

The first signal given when the seismic system is in place above them is three shots (explosions) detonated at the surface. These shots can easily be heard underground. At this signal, the trapped miner(s) must pound 10 times on the roof of the mine with a heavy object like a timber. This pounding is repeated every 15 minutes. This creates a pattern of seismic signals that propagate through the earth and reach the subarrays at the surface. The signals from each subarray are amplified and telemetered to the seismic truck, where they are filtered to reduce interferences, amplified, and recorded on analog magnetic tape. They are then band-pass filtered from 20-200 Hz and displayed on an oscillograph recorder.

The operator observes the record and decides whether or not the seismic signals are the result of underground pounding. The key, of course, is the series of 10 events repeated every 15 minutes. If such signals are observed, that portion of the magnetic tape is input into a computer which processes the data, taking into account the relative arrival times at the various subarrays. These data, along with information concerning the location of the subarrays, and the seismic velocity of the geologic strata, are used to calculate the location of the underground source. Under favorable conditions, the system can detect these seismic signals from a distance of about 600 m (2000 ft), with a location accuracy of about 30 m (100 ft). When the surface seismic team has ascertained the location, they detonate 5 explosive shots. This is the signal to the trapped miners that they have been detected and located. They should now stop pounding, and wait for rescue.

Seismic systems have application for detecting persons buried in landslides and collapsed buildings as a result of earthquakes or other natural disasters. However, a surface disaster is quite different from a mine disaster. In a mine disaster, the victims are trapped perhaps hundreds of meters from where geophones can be deployed. Also, there is no way of knowing exactly where the miners might be. In such a situation, detection is not enough. Accurate location is needed also. Both of these requirements can be met using seismic techniques, because the nature of the seismic path between the mine and the surface can be measured. In a surface disaster situation, the most important aspect is to verify whether or not there are survivors within a localized area. Rescuers generally know approximately where to look, because the distances involved are measured in tens of meters, not hundreds. Computer-based seismic location techniques, such as those used in the mine disaster situation, would not likely be successful in the surface case because of the chaotic and unconsolidated nature of the material between the victim and the geophones. These circumstances call for a different kind of seismic system, such as the one built by MSHA and successfully used in the Mexico City earthquake rescue efforts in 1985. This system, known as the "mini-seismic" system, was originally built for in-mine use, and can be carried by an advancing rescue team. It consists of three geophones, three preamplifiers, three filters, and a chart recorder. It is a detection system only, and has no computer-based location capability.

The human operator visually examines the magnitude of the three seismic signals, and decides which is the greater. The assumption is that the geophone registering the largest signal, is the one nearest the seismic source. By a series of measure and move operations, the system can zero in on the location of the seismic source.

MINE FIRE DIAGNOSTICS

Mine fire diagnostics are a set of techniques by which the mine air is sampled for combustion products to determine: 1) during the early stages of a fire, the status of the fire, in terms of its size and possibly the primary combustibles involved; or 2) after a mine, or a section has been sealed, whether or not a fire still exists, and if so, whether or not the fire is smoldering or flaming.

It is important to realize that in addition to diagnostics for fires, similar diagnostic procedures are also used to determine the explosibility of the mine atmosphere due to the accumulation of methane and other explosive gases. For either type of diagnostic, fire or explosibility, the basic techniques are the same. These techniques consist of obtaining gas samples from various mine locations, analyzing these samples, and interpreting the meaning of the resultant gas concentrations as they apply to either a fire or the explosibility of the gaseous mixture.

The differences in these techniques, as they apply to either of the two situations, are the result of the time-scales involved which dictate that different sampling, analysis, and interpretation procedures be used.

Situation No. 1
Diagnostics that are intended to determine fire status, fire location, and possibly the primary combustible involved must be rapid. In this instance, particularly with regard to fire-fighting strategy, time is critical. As much information as is possible regarding the fire must be obtained in a minimum amount of time. To implement a successful fire-fighting mission, several factors are critical:

1) Location
2) Accessibility
3) Fire Size and Growth
4) Combustible Type

Once the location of a fire is known, a determination of its accessibility must also be made. In very general terms, most fires are limited in their accessibility due to the smoke produced which reduces visibility. In particular, if the ventilation air velocity in the fire-affected entry is less than some critical level, reverse, stratified flow of smoke and other product gases can occur, thus limiting accessibility from the upstream side of the fire. This critical velocity is predictable from the expression

$$v_{crit}(m/s) \leq \left(\frac{gh}{10}\right)^{1/2}$$

where: $g = 9.8\ m/s^2$
h = entry height (m)

For instance, if the location of the fire is in an entry with a height of 1.5 m (5') and the air velocity in that entry is 0.50 m/s (100 fpm), then the fire-fighting team should expect to encounter smoke and reduced visibility from the upstream side of the fire, since the critical velocity for this entry is 1.2 m/s (240 fpm). This does not necessarily mean that some effort should be made to increase the air velocity because increasing the air velocity may enhance the flame spread of the fire in many cases, such as conveyor belt fires.

The decision to increase ventilation can more realistically be made if the fire size is known, or if the type of fire is known (i.e., flaming vs smoldering). This information can be obtained by measuring the levels of the gases, CO and CO_2, downstream of the fire. The level of CO_2 is an excellent indicator of the intensity of the fire. Some benchmark values of the CO_2 level can provide insight as to the stage of the flaming fire, and the ratio of CO to CO_2 can provide additional information on the type of fire. For a typical mine entry cross-section of 9.3 m^2 (100 ft^2) these levels are:

a) ppm $CO_2 < 150$ and $CO/CO_2 \geq 0.5$ indicates a smoldering fire in its early stages of development;

b) $150 < ppm\ CO_2 < 1500$ and $CO/CO_2 \leq 0.10$ indicates a localized flaming fire that is not spreading;

c) ppm $CO_2 > 1500$ and $CO/CO_2 \leq 0.10$ indicates a spreading fire that is fuel-lean;

d) ppm $CO_2 > 1500$ and $CO/CO_2 > 0.10$ indicates a spreading fire that is fuel-rich.

In addition, the absolute levels of CO provide information relevant to the toxicity of the atmosphere. For CO levels less than 250 ppm, no severe toxicity hazard is present from the CO. However, if combustibles other than liquid fuels, coal, or wood are involved some high level of toxicity may exist due to other gases. For instance, if chlorinated combustibles such as PVC or Neoprene conveyor belt are involved, elevated levels of HCl may be present; if nitrogen-based combustibles such as polyurethane foams are involved, elevated levels of HCN may be present.

It should also be mentioned that elevated levels of smoke, in excess of some critical level for visibility, often exist at very low levels of CO. In fact, the critical level of visibility for human escape is generally accepted to be 3.7 m (12 ft). This level of visibility occurs at a CO level of 20 ppm. In other words, severe reductions in visibility due to smoke can usually be expected, and often occur at relatively low levels of CO and other toxic gases.

It should be noted that the ventilation airflow serves to dilute the combustion product gases and smoke. As a result, when it is necessary to base some decision on the absolute level of either CO or CO_2, every effort should be made to make this measurement at a location downstream of the fire where the gas levels are due only to the ventilation airflow within the affected entry that is affected and not at some location where these gases may have been diluted by airflows from adjacent entries.

All of the above information applies to rescue operations, as well as fire-fighting. However, in assessing the feasibility of rescue operations, it is also necessary to obtain information about the level of O_2 present in order to assess the breathability of the atmosphere. Diagnostics for explosibility are also necessary.

These initial diagnostics need to be acquired rapidly and reliably because decisions need to be made quickly. As a result, the use of handheld gas analyzers for the primary gases CO, CO_2, CH_4, and O_2 is usually required. Such devices are generally available commercially.

Situation No. 2

Usually, the sealing of a mine, or section of a mine, is done as a last resort following unsuccessful local fire-fighting efforts. The intent of sealing is to allow the fire to self-extinguish as the supply of O_2 is gradually depleted. Unlike diagnostics for the early stages of a fire, time is not a critical factor in this situation. The Bureau of Mines has developed various gas ratios to assist in determining the status of fires in mines that have been sealed. Gas ratios are used instead of absolute concentrations because: 1) sealed areas enclose large volumes, so ratios are used in order to eliminate dilution effects; and 2) the typical time scale for attempting to recover a sealed mine is generally in the range of 2 to 12 months, but can be longer, and trending of gas ratios during this period is extremely beneficial.

The important thing to remember is that the bulk of necessary information for effective mine fire fighting can be obtained from the measurement of only four gasses: CO, CO_2, O_2, and CH_4. Only in fire emergencies involving gasses more toxic than CO, is it necessary to monitor these other gasses. These same techniques have direct application for attacking fires in any confined space, specifically, tunnels, and underground storage facilities.

CONCLUSION

Three USBM research areas were discussed: Life Support; Trapped Miner Location; and Mine Fire Diagnostics. The genesis of this research was to mitigate the consequences of mine disasters which are caused by underground fires or explosions. However, much of this work has direct application to search and rescue situations, such as: emergency evacuation through smoke-filled or otherwise unbreathable atmospheres, locating and rescuing survivors from rubble piles, and fire fighting in confined spaces.

ALL CHANNEL ALERT
Message Distribution System

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Abstract

The All Channel Alert (ACA) system is a video and audio processor which uses a cablesystem interface to display static and moving messages on selected channels. It utilises an existing character generation device and communications interface with software and memory to provide full functionality on each individual channel. Each rack mountable ACA unit provides up to 36 channels enough to support a typical cablesystem and three units can provide a maximum of 108 channels when they are connected together in a daisy chain fashion.

1.0 Background

The ACA was developed in Canada by Pelmorex Communications Inc. which owns and operates two satellite-to-cable television networks broadcasting meteorological and environmental information in English (The Weather Network) and French (MétéoMédia). In answer to a proposal requested by Environment Canada's Atmospheric Environment Services (AES) for a national weather warning delivery system, the ACA evolved into a multi-leveled distribution system interfacing cable and broadcast television with civil protection agencies (federal and provincial) via satellite.

Following discussions with potential users and representatives from the broadcast industry, a fail-safe ACA will be implemented in Canada this year as the national Emergency Broadcast System under the auspices of Emergency Preparedness Canada and Industry Canada. AES will be the most frequent users displaying only the most severe warnings such as tornadoes or unforecasted snow storms. Currently, weather warnings issued by AES are always displayed on The Weather Network and MétéoMédia on a priority basis, this system will continue to be used for lower priority weather warnings.

The following will discuss the design of this system which will be implemented as the national Emergency Broadcast System to warn Canadians of impending danger.

2.0 ACA System Overview

The system is composed of the Network Controller, the Command Centre and the ACA unit; the cable company provides the necessary link between the Network Controller and the ACA unit. As illustrated in Figure 1, an incoming message is received at Pelmorex's broadcast centre where it is pre-processed by the Command Centre which verifies the messages for errors and compliance to format. The Command Centre then addresses and configures the data to be transmitted via satellite to the Network Controller located at the cable headend. This procedure is fully electronic and requires no human intervention.

2.1 Network Controller

The Network Controller receives a baseband data subcarrier via the satellite receiver at the headend and determines if the data has been addressed to it for post processing. If so, it processes the data for immediate transmission to the ACA unit with the appropriate command instructions; otherwise, the data is ignored.

Located at the cable headend, the Network Controller is the company's current broadcasting infrastructure and for the ACA system provides the logical link between the Command Centre and the ACA unit. This proprietary technology is individually addressable geographically by the Command Centre and thus is capable of locally

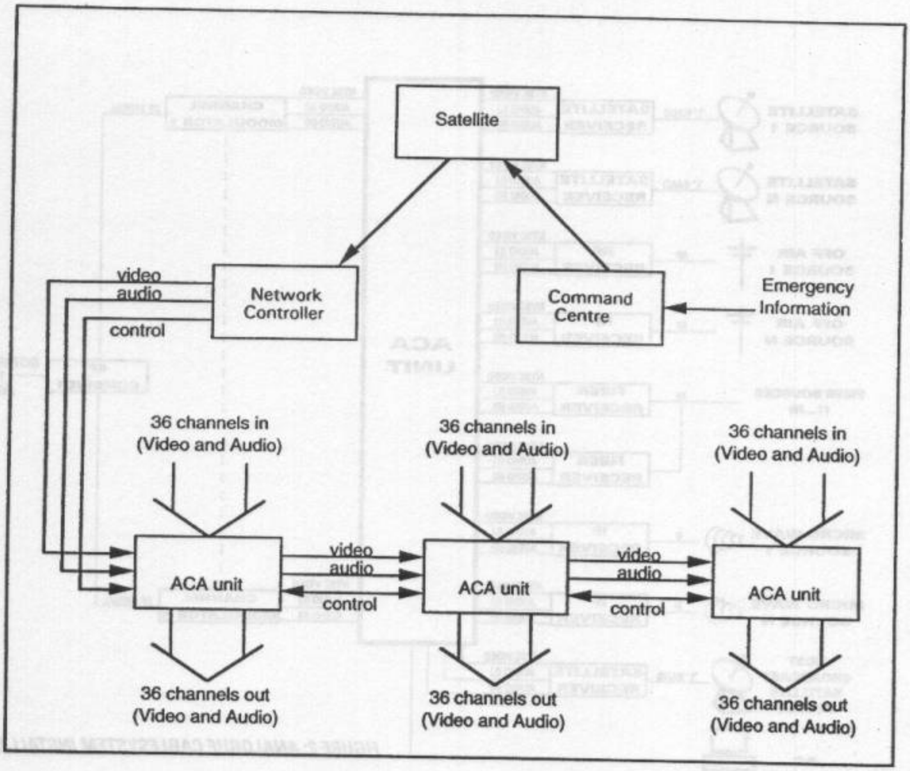

Figure 1 System Overview

distributing information pertinent only to a small community.

The provision for a local PC to be incorporated in the ACA chassis to operate the ACA system without the Network Controller.

2.2 ACA Unit

The analogue ACA unit receives data and command instructions from the Network Controller and places static or moving messages on any or all NTSC video and unmodulated audio processed by the unit. Each NTSC channel board supports 4 channels with up to 9 boards for a maximum of 36 channels per chassis. A maximum of 108 channels is obtained by daisy-chaining three chassis together.

The modular design of the ACA enables it to evolve to meet present and future functional requirements. It is anticipated that the ACA will be altered to keep pace with technological changes in the cable industry which will focus around digital video compression. Each analogue unit is easily replacable with a digital one. The chassis will be described further in this document.

2.3 ACA Functionality

(1) <u>Message generation</u>

An integrated character generator is built into the ACA to generate text. A customised chip defines a set of 128 different characters and can generate English as well as French text.

Messages can be displayed as static or as moving at a fixed rate horizontally or vertically. The text can appear as a line, a partial or full page of characters displayed statically, as a single line of text crawling horizontally across the screen at any

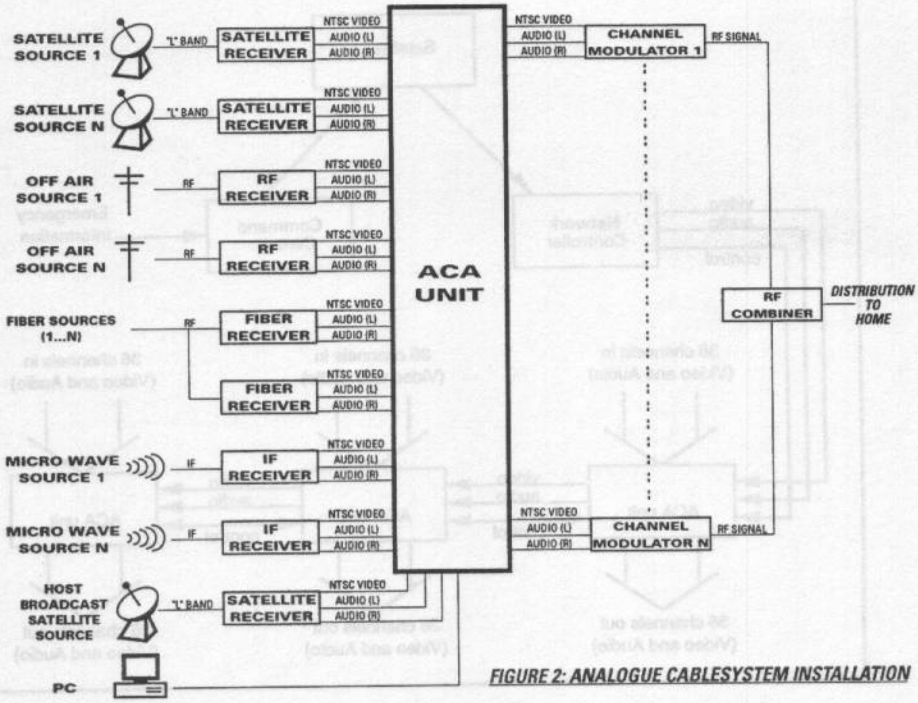

FIGURE 2: ANALOGUE CABLESYSTEM INSTALLATION

one of 10 line position available, or as up to 240 line of contiguous text scrolling vertically. Approximately 12 seconds are given for both horizontal crawl or vertical scroll to traverse the screen.

(2) Control

Control is executed through the Network Controller via a standard interface such as RS-232 of RS-422. The functionality provides for the insertion of a number of messages on different channels at different times while allowing, but not limited to, English and French message generation within the same ACA unit. Since each channel chip has its own character generator chip, the interface is language independant; furthermore, each channel can operate independant of each other. The ACA places a valid message on the channels within seconds of being instructed to do so.

(3) Video switcher

The ACA provides the ability to input NTSC video and unmodulated audio as well as RF and IF modulated video and audio, as shown in Figure 2. The output signal is NTSC video and unmodulated audio regardless of the input signal.

The ACA is also capable of inputting and switching an override video and an override audio onto one or a group of channels. Synchronisation of video switching from one video source to the other is controlled by the Network Controller which instructs the ACA to switch the videos at the appropriate time. Synchronous and asynchronous video switching becomes necessary when commercials are interrupted on American and Canadian programming schedules.

3.0 The ACA Chassis

The ACA chassis is constructed of a modular architecture grouping blocks of boards in different modules, as illustrated in Figure 3. The three modules consist of the AT backplane, the ACA backplane and a power supply which provides the power required in the ACA unit.

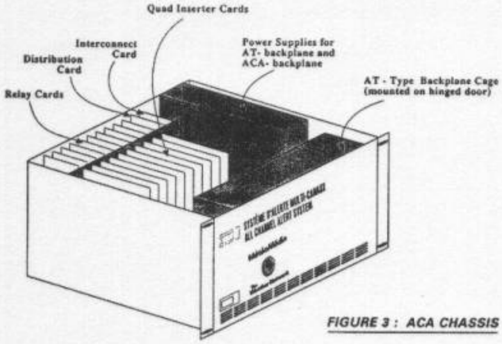

FIGURE 3 : ACA CHASSIS

3.1 The AT backplane

An AT passive backplane assembly capable of taking in 6 PC cards. The cards are fully accessible from the front of the unit and may be installed or removed without removing any chassis parts. Additionally, a local equipped PC can be incorporated on the AT backplane to control the ACA unit in the absence of a Network Controller.

3.2 The ACA backplane

The ACA backplane and cardguides form a second sub-chassis within the box. The backplane is used to provide the mechanical and electrical interface between the video and audio connector input and outputs, and the video and audio processor boards. It also allows digital control signals and selected video and audio signals to be bussed to all boards. The cards connected to the backplane are described below.

3.2.1 Quad Inserter

The channel cards comprise the largest functional block within the ACA chassis and contain video and audio control circuitry to implement the various required modes of operations: providing channel or replacement video, with or without overlaid character data. A micro-controller provides the local intelligence within the ACA system accepting serial commands and data from an external controller and performing the required operations.

As the name implies, each channel card processes 4 channels of video and audio. Each Quad Inserter is interconnected to an associated relay card via the backplane, it controls the video and audio by-pass relays directly.

Each card assumes an address from the backplane connector which allows it to identify the chassis and slot number where it has been installed. This allows commands to be sent to individual quad inserter cards within an ACA system. Each video channel provides the vertical interval flag to the micro-controller sector to synchronise display operations and to indicate whether a video signal is actually connected to the channel. Further, the analogue section contains video buffers and electronic switches to select either the channel video signal or the replacement video signal. The character generation and overlay device is also electronically switched in or out of the circuit as required.

3.2.2 Relay Cards

The ACA relay card is a subassembly comprised of a printed circuit board and a metal panel; the panels form the major portion of the rear panel of the unit and functions as a modem between video and audio signals and channel control circuits.

All cable channel video and audio signals are connected to the relay card. Each board holds the relays which physically bypass the video and audio signals in case of power failure or system malfunction. The audio bypass relays are also used to select the replacement audio signals.

4.0 ACA Design Results

To design a user friendly, cost effective and widely available system, Pelmorex met and exceeded the requirements implied in the initial proposal. The following results are thus obtained:

(1) Ease of use

The input of text messages is highly centralised and requires only a basic word processor. The data path thereafter is entirely automatic and requires no human intervention.

(2) <u>Realtime access</u>

Validated and formatted data sent to the ACA unit appears on the television screens immediately. At the same time, video and audio products can be made available to the local television and radio broadcaster if required.

(3) <u>Addressability</u>

By utilising an existing addressing structure such as the Canadian postal codes and the Network Controller at local cable headend, highly local messages can be delivered to the desired community, on an individual channel level.

(4) <u>Affordability</u>

The target cost for manufacturing the ACA system in volume is C$1800 per unit, or C$50 per channel.

(5) <u>Upgradeability</u>

The modular design of the ACA unit allows future modifications to one block without interrupting the others. This is intended for keeping up with changing technology.

5.0 Conclusion

The first field testing of the ACA units across Canada is scheduled for mid 1994. Pelmorex Communications Inc. will act in collaboration with the various levels of governments and the broadcast industry to establish, install and operate the first Emergency Broadcast System in Canada by utilising cable and television broadcast technology.

Through this valuable cooperation of private industry with the public sector, the ACA has evolved as a unique and innovative solution to the long-standing challenge of implementing a national warning system in Canada.

SIMULATION OF POSITIVE PRESSURE VENTILATION (PPV) FOR FIRE FIGHTER TRAINING

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ABSTRACT

As new technologies and emergency management tactics are introduced into fire agencies, additional education and training become necessary. Due to the costs and hazards of live fire exercises, simulation is gaining acceptance for use in training programs for fire fighters.

PPV is a relatively new technique for attacking and combating structural fires which, when properly implemented, can reduce property damage and save lives. Proper use of the technique requires special training that can, in part, be realized through physical and computer simulation.

This paper reports advancements in PPV simulation for fire fighter training. Physical, scale model simulations are addressed and supported by live fire tests. Results from this research are being used to generate the data and experience base necessary for future computer simulation.

INTRODUCTION

Using simple fans, a structure (building, house, aircraft, etc.) can be slightly pressurized to provide rapid and effective removal of heat, smoke and toxic gases as conceptually illustrated in Figure 1. This fire fighting technique is known as Positive Pressure Ventilation (PPV) and has been shown to improve the environment inside the structure by lowering temperatures, improving air quality and increasing visibility [1,2,3]. The benefits of PPV include enhanced search and rescue operations, reduced property damage and minimized long-term adverse health effects for fire fighters. Although PPV use during post-fire salvage and overhaul operations has become popular within recent years, it is rarely used or taught as an initial fire attack technique where it's benefits may be more fully realized.

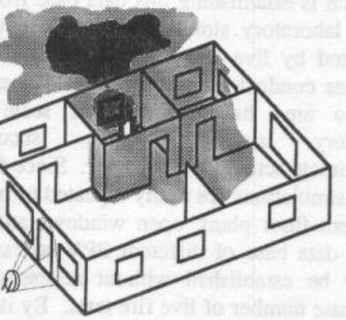

FIGURE 1 Conceptual Illustration of Positive Pressure Ventilation

Training and practice are required in order to use PPV techniques effectively. Unfortunately, the fire service is limited in its ability to safely and repeatedly expose personnel to various live fire emergency training scenarios while at the same time complying with a variety of state and federal mandates. Although training fires can be staged in condemned or donated structures and specially constructed burn buildings, the safety and health hazards to which personnel are exposed pose additional liability and concern for training program managers. Asbestos, heat and toxic combustion products produce an excessive hazard to personnel while in a training environment. Since training is vital to a fire fighter's well-being, accurate simulation of techniques such as PPV is desirable.

For the past 18 months, UCF and OCFRD have been conducting a research program to evaluate the merits of PPV and to develop the tools necessary for fire fighter training. The ultimate goal of these efforts is to develop a simple, user friendly, PC-based computer simulation package that can be incorporated into any comprehensive fire fighter training program.

In order to accurately simulate PPV and assess the validity of computer simulation, a large, reliable data base must be established for comparison. Research is establishing this data base from scale model laboratory simulations which in turn are supported by live fire tests. Live fire training exercises conducted in donated residences in the Orlando area have shown that scale model laboratory simulation can successfully approximate actual PPV behavior. Since the scale model simulations are easily repeated or modified (different floor plans, open windows and doors, etc.) a data base of different PPV scenarios can readily be established without necessitating an inordinate number of live fire tests. By itself, the laboratory simulation has proven to be useful in fire fighter training for both exercise planning and post fire evaluation.

The software for computer simulation is in the early stages of development and consequently results are not presented here. Unlike existing CFD or zone model codes which require extensive computer knowledge and expensive state-of-the-art computational hardware to use, the code being developed is more amenable for training. The real-time code is based in modeling momentum driven flows similar to the laboratory simulations.

SCALE MODEL SIMULATION

A novel underwater simulation technique for PPV has been under development at the UCF Two-Phase Flow and Heat Transfer Laboratories. Scale models of structures are constructed of thin, clear acrylic for easy viewing of hot and cool air masses simulation by colored water injection. The simulation is conducted either on a water table or in a deeper transparent tank built to accommodate taller multi-story models. Simulations have been conducted for a series of live fires that were fought with and without the PPV technique (1992-1993). Each fire was instrumented with thermal, chemical and video sensors to monitor the fire fighting environment and provide verification of the laboratory simulations. Results show that live fire testing supports the accuracy of the real-time simulations.

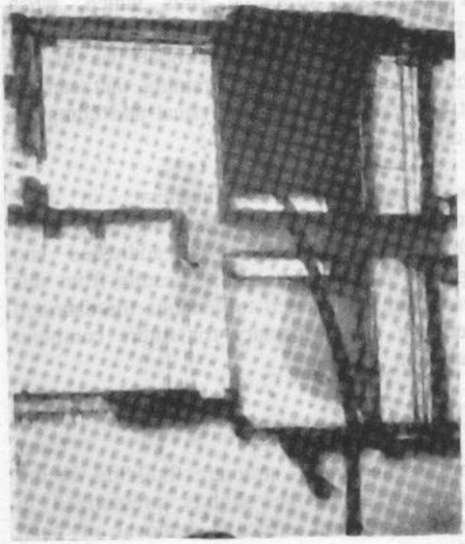

FIGURE 2 Underwater Scale Model Simulation of Heat Spread
(Dark areas show heated air as it moves through the house)

As shown in Figure 2 the simulations can be used to vividly illustrate the spread of heat from isolated fire sources and to identify "hot spots" within the structure. Laboratory simulation is a safe and cost effective (less time, manpower, equipment) alternative to live fire testing for demonstrating proper and improper PPV techniques and it permits a spectrum of training scenarios to be quickly evaluated. Visualization of the entire PPV process is possible with a laboratory simulation allowing all personnel to witness the effects of heat movement and ventilation that are not apparent during a real fire. Also, fire and ventilation scenarios are repeatable and lend themselves to easy variations within the laboratory and any errors in judgment regarding implementation of PPV present no hazard to fire fighters, civilians or property when executed in a laboratory environment.

The thermodynamics and fluid mechanics of the fire and PPV are simulated by injecting red colored water dyes at a rate determined from actual fire measurements. Buoyancy effects can be approximated by vertical water injection or by fresh water injection into a salt water filled model. A similar underwater technique was successfully used by Steckler et al. [4] for simulating the spread of heat during on-board ship fires.

The time history of the temperature changes in the fire room is important for simulating the expansion of heated air. Air expands when heated and a relationship exists that relates the change in air mass for a given temperature change. For a constant volume structure at constant pressure:

$$m_2 - m_1 = \left(\frac{PV}{R}\right)\frac{T_1 - T_2}{T_1 T_2} \qquad (1)$$

The left hand side of this equation is the change in air mass in a room over a specified period of time. Pressure (P), room volume (V) and the specific gas constant (R=287 N-m/kg-K for air) are essentially constant and do not change with temperature (T). T_1 and T_2 are the values of temperature at the beginning and the end of the specific time interval.

Time and temperature data from the live fire tests were used to verify the simulations. The temperature curve presented in Figure 3, for example, is for a rapidly burning fire based on measurements made during a residential fire test. It shows how temperature varied with time as measured by a thermocouple inside the fire room. The jagged line shows the actual temperature measured during the fire and the straight lines show the approximation used for simulating the fire.

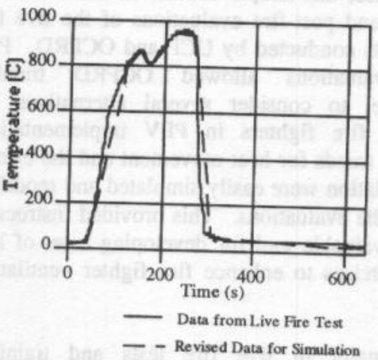

FIGURE 3 Sample Temperature versus Time Trace for Simulation [5]

Since heated air expands and flows out of a burning structure, the volumetric flow rate of the air (Q_{heat}) can be approximated by

$$Q_{heat} = \frac{(m_2 - m_1)_{air}}{(t_2 - t_1)\rho_{air}} \qquad (2)$$

where t_2-t_1 is the time interval for a given temperature change (T_2-T_1) and ρ is the average density of the air. To simulate an actual fire and ventilation process, the water injection rates are simply scaled by

$$Q_{model,heat} = \frac{V_{model}}{V_{real}} Q_{heat} \quad (3a)$$

and

$$Q_{model,fan} = \frac{V_{model}}{V_{real}} Q_{fan} \quad (3b)$$

where Q_{model} is the water injection rate into the model and V_{model} / V_{real} is the model to real volume structure ratio.

In practice, this simple simulation has been used for pre and post-fire evaluations of the live fire PPV tests conducted by UCF and OCFRD. Pre-fire evaluations allowed OCFRD training personnel to consider several alternatives for training fire fighters in PPV implementation. General trends for heat movement and the effects of ventilation were easily simulated and modified during the evaluations. This provided instructors with a valuable tool for developing a set of live fire exercises to enhance fire fighter ventilation training.

Occasionally in live fire tests and training, unexpected events occur. Data analysis and post fire simulation of live fire tests can supply a useful reconstruction of events and environment changes that may illustrate the cause of these unexpected occurrences. Post fire simulations also highlight the merits or the harm of certain fire fighting tactics. In particular, simulation can show fire fighters the benefits of PPV when it is properly applied and the potential problems of improper implementation.

RESULTS AND SUMMARY

Nine structural research and training fires were ignited and extinguished in four donated residences in the Orlando area. Each fire was simulated with the underwater scale model method described.

1. Based on actual live fire tests, PPV has been shown to be an effective fire attack tool that can significantly reduce temperatures, lower levels of toxic combustion products and greatly enhance visibility. Training is required to properly implement PPV and simulation can support a training program.

2. Underwater, scale model physical simulations add to the learning and training process by accurately simulating heat spread and ventilation. Table I shows a representative comparison of live fire events to those simulated with underwater models. As shown, live fire behavior is accurately represented in real time by using the simulation technique described in this paper. Hence, a large data base of PPV experiences can be gained through simulation with an expected high level of confidence.

TABLE I Comparison of Real Fire and Simulation

Scheduled Event	Real time (min:s)	Simulation time (min:s)
Start of Fire	0:0	0:0
TC in hall responds	0:30	0:22 - 0:40
TC1 in BDRM #1 responds	0:50	0:50 - 1:00
TC2 in BDRM #1 responds	1:25	1:15 - 1:25
Fire room window breaks	1:42	1:42
TC in BDRM #3 responds	1:50	1:50 - 2:00
PPV fan ON	2:12	2:12
Fire Out	4:30	4:30

3. Results from the scale model simulations can be used to develop and test future computer simulation packages. A simple PC-Based computer package is currently under development which incorporates the simple momentum and buoyancy driven flow behavior indicative of the scale model simulations.

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ACKNOWLEDGMENTS

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TECHNOLOGICAL DISASTERS

ISEM — An Information System for Emergency Management

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Abstract

In an Esprit II-project partly funded by the European Commission a prototype of a generic information system supporting the preparedness organization in severe industrial accidents has been developed. Based on a thorough analysis of functional and information and communication needs within the preparedness organization two demonstration systems were set up. The ISEM consortium involved participants from seven European countries, which enabled the project to draw on knowledge of and experience with a wide spectrum of European emergency management practices.

1. Introduction

The potential risk of critical situations at industrial plants, still increasing in complexity and size, has drawn increased attention to emergency organizations coping with such situations. Experience gained from previous incidents and emergency drills has revealed the complexity that must be faced in making these organizations work properly. To meet the requirements of a distributed emergency management, capable of coping with seriously critical situations, puts heavy demands on the kind of preparedness system supporting such efforts - on the accessibility of information, situation assessment support, resource allocation, and communication support.

2. Conceptual model

The consortium has developed a number of conceptual models describing various aspects of emergency management and the relevant organizations.

The organizational model has been the basis of the organizational structure for the demonstrators developed within ISEM.

We have found that the organizational set-up for emergency management in process industries is characterized by (see Fig. 1)

- the goals involved: economic operation, plant integrity, and public protection
- the extent of authority involved: on-site, off-site local environment, national environment

Figure 1 shows how the organizational set-up is changing as an accident (e.g. in a nuclear power plant) turns into a larger emergency. The chart can be interpreted as follows:

- In a normal situation the goal is economic operation of the plant and the unit in charge of this is the control room staff.
- An accident may cause the technical management to be alerted to take the overall responsibility. The overall goal is plant integrity.
- A severe accident may require the on-site emergency operation centre (EOC) to be set up and the local off-site EOC to be notified.
- If there is any risk of adverse consequences outside the plant the situation will change from a site emergency to a general emergency. The organizational set-up will rapidly escalate to comprise many different organizations. The overall goal is now public protection.

3. Functions

At each stage of the emergency the entire

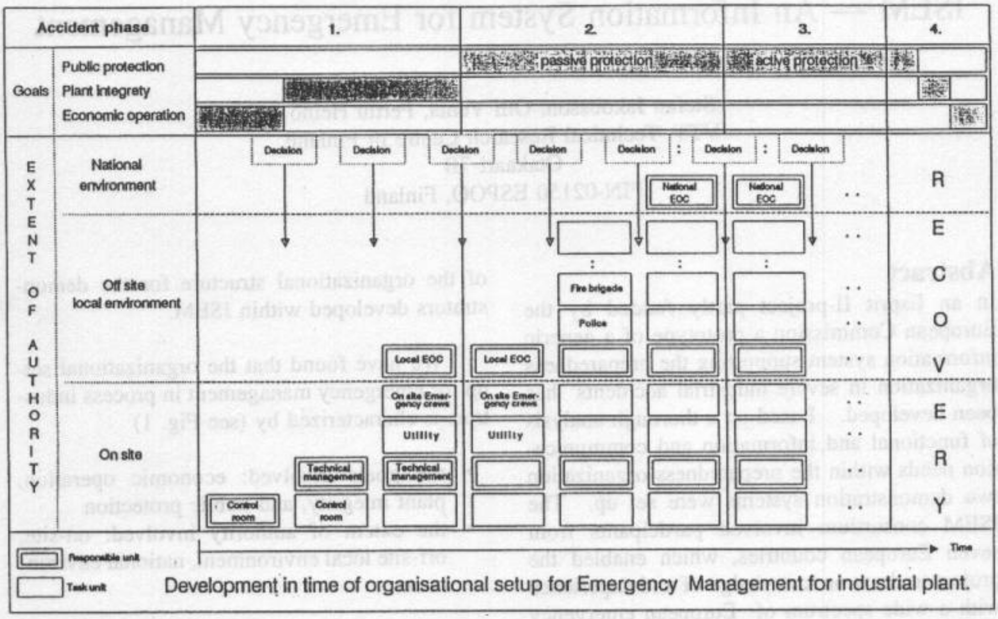

Figure 1. Generic representation for the process industry.

emergency organization has to fulfil the following general functions or tasks:

- assessment of the current state and current prognosis for the plant/environment
- assessment and possible revision of the current priority of overall goals
- assessment of the need for additional actions and agents: decision whether to alert additional agents
- establishment of communication links with units and agents
- distribution of tasks and the co-ordination of information to relevant units and agents

These general functions may be seen as methods for the entire present organization to define specific functions for each part of the organization. The general functions are the framework within which decisions are made whether to shift from one level of activity to the next.

An extensive list of functions useful for support of the users in critical situations has been elaborated based on interviews with end users and experts. These functions have been decomposed into activities and regrouped into a set of composite functions, called *functional modules*, which have been developed in the project.

The group of functional modules chosen to be developed was the following, each characterized by a short description:

Situation assessment, on-site and off-site.

Get and create the data needed in order to be able to understand the current situation.

- get the available information relevant for

managing of the emergency. Pieces of information can be either readily available or they must be actively fetched as indicated by the preparedness plan
- get information about all plant data of vital importance for emergency evaluation
- interpret and update the emergency situation by calculations, analysis, and diagnosis
- make predictions of what will happen.

Part of this module is a radioactive dispersion and dose calculation model.

Extended preparedness plan

In this module all events, decisions, actions, procedures etc., which can be planned in advance be entered, changed, updated and compared to the actual situation to benefit from foreseen resembling situations. Well structured parts of the preparedness plan (emergency procedures etc.) were implemented as a database application, while textual background data was implemented in hypertext. Links between the two formats allow direct jumps in between.

Activities and resources

Here decisions on actions to be taken and allocation decisions are recorded as a response to evaluation using information from the situation assessment module. All decisions are made by human operators, the system provides the necessary information.

Information exchange

This is basically an E-mail system specially adapted to the needs of the emergency management domain. E-mail on X.400 and fax services are supported. For more information on this matter see [2].

Apart from the functional modules above a few other were also partly implemented, the training module most notably.

4. Database

An extensive data model was developed including data relevant for a wide range of emergency management activities. The data model describes e.g.

- data from the plant (a subset of the most important data)
- event and actions related data
- organizations and agents
- procedures to be followed
- decisions
- resources
- environmental monitoring.

Many of the data items can be described as having a quite complex life cycle: all static data that can be planned in advance is called preparedness plan data. With a real situation at hand this may be updated and turned into 'actual' data describing the current situation. Other states of the data are data on predicted situations, and even scenario data for training purposes.

5. Platform

ISEM is implemented on standard UNIX workstations and PCs using standard relational database technology. Two demonstrator systems were set up, one for the nuclear sector and one for a chemical plant. A schematic view of the architecture and set-up for the nuclear demonstrator including the data is shown in figure 2.

5.1 Software

The ISEM programs run on an Oracle relational database, MapInfo GIS system (Geographical Information System), Xantippe hypertext, X.25/X.400 communication, Unix sockets and the OpenWindows graphical interface.

The hypertext environment used was partly developed within the project. The Xantippe hypertext system is built on top of Eiffel and can run both on DOS and UNIX platforms. Xantippe was used for the following purposes

- to implement the help facility
- to provide the information navigation tool
- to provide a textual presentation of background information (also images)

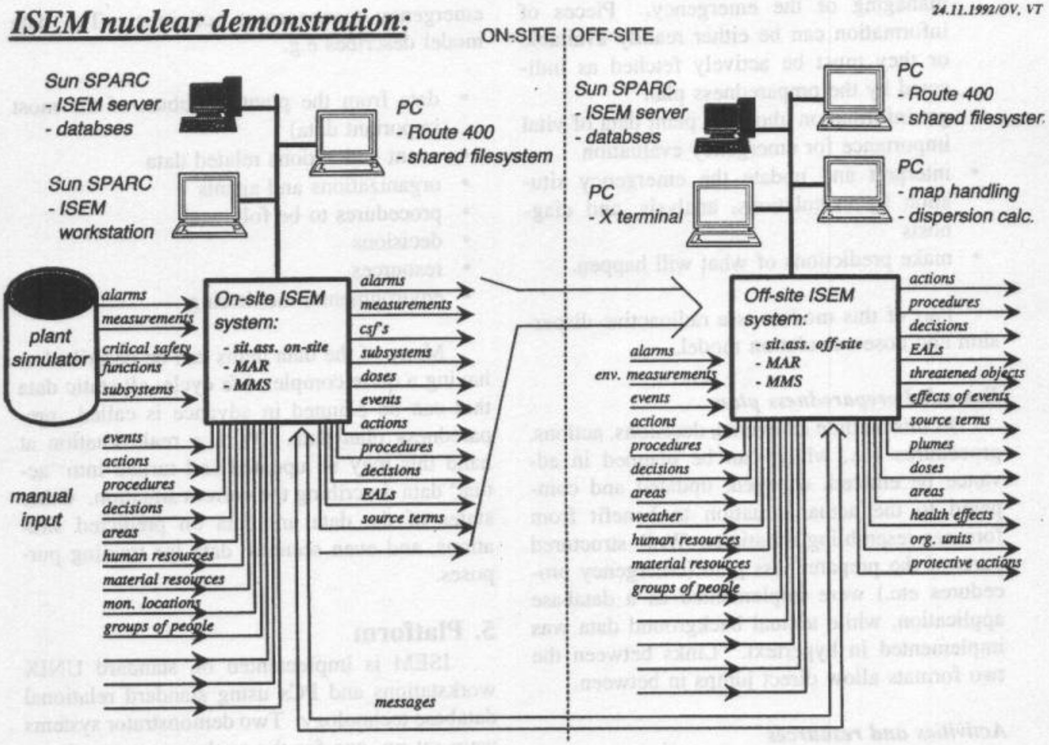

Figure 2. Set-up for the nuclear demonstrator.

- to execute database and other applications from within Xantippe.

The GIS of choice is MapInfo, which was used for display of dispersion and dose calculation data, population data, environmental monitoring data and certain infrastructure data. The dispersion model running on a PC gets the input data from the database.

5.2 Hardware

Each site with an ISEM system has a central database connected to a local area network, LAN, which is an Ethernet in our case. The database is running on a Sun SPARC server. XTerminals running the database applications are connected to the LAN. Also PCs running special applications, like GIS and dispersion calculation, are on the LAN and can access the database where appropriate. The demonstrators with several ISEM sites were connected over the X.25/X.400 network.

6. Conclusions

The key points describing ISEM:

- integrates on-site and off-site emergency management support
- provides integration and capability of
  - resource management
  - access to preparedness plan
  - on-site and off-site situation assess-

ment
- a dedicated information exchange system
- training

- provides integrated support for co-ordinated emergency management efforts among different types of organizations
- has been validated across two typical emergency management domains, the nuclear and chemical sector, in terms of demonstrator tests
- has had its data model validated for the domains in question in a similar way

ISEM is, however, still a prototype. MEMbrain, a EUREKA project, which will develop and make commercially available a system to support the major activities of emergency management organizations, will use ISEM as one of the building blocks.

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A GENERAL ENVIRONMENT INFORMATION SYSTEM FOR DECISION SUPPORT DURING MAJOR EMERGENCIES

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Abstract

During a major emergency human life, the environment and/or property are threatened. This paper describes an Environment Information System (EIS) being so general that it may be custom-made to meet the needs for monitoring and prediction purposes of the environment during most Major Emergencies.

The EIS shall meet the need for <u>past</u>, <u>present</u> and <u>near future</u> information on the environment. It forms one of the Work Packages (WP) of the EUREKA project MEMbrain (MEM = Major Emergency Management).

1. Introduction

The Norwegian part of MEMbrain is funded by Ekspomil of the Norwegian Research Council, the Norwegian Industrial Fund and six Ministries of the Government.

The EIS described herein is a general one based on which customized applications can be made to meet many special needs.

<u>MEMbrain</u>

The EUREKA initiative was created in 1985 by 20 European countries and the Commission of the European Community. It seeks to strengthen productivity and the competitive position of industry and national economies on the world markets. The EUREKA framework aims to further European-wide cooperation in advanced technology projects with civilian ends.

To obtain EUREKA status project must meet the following criteria:

- cooperation between participants (enterprises, research institutes) in more than one European country.
- the use of advanced technology.
- the aim of securing a significant technological advance in the product, process and service concerned for which a viable international outlet exists.

MEMbrain is a European project that aims at producing a hardware and a software platform for the integration of decision-support systems in the Management of Major Emergencies. The MEMbrain consortium brings together major actors from six European countries.

Following is a description of the project partners and their contributions:

- Cap Gemini Innovation, France
  - an integrated control and command workstation.

- INERIS (Institute de l'Environment Industriel et des Risques), France
  - reliability, validation and robustness of sensors.

- OCEANOR (Oceanographic Company of Norway AS), Norway
  - integration of heterogeneous environment monitoring systems.

- QUASAR, Norway
  - an evacuation management system as well as a chemical and radioactive substances information system.

- Athens Technology Centre, Greece
  - telecommunication platform

- Instituto de Ciencias de Terra e do Expaço, Portugal
  - modelling of natural hazard

- Risø National Laboratory, Denmark
  - a message management system as well as cooperative training system.

One of the goals is to contribute to a European standard for crisis management. MEMbrain products will be available in 1995.

Potential customers are invited to influence the project products.

The MEMbrain system will be tailor-made to fit scenarios of both natural and technological characters, e.g., landslides, floods, nuclear accident, chemical accident, oil spill etc.

The following functions planned for MEMbrain are non-existent in presently available systems:

- Module for analysis of the major risks in advance of the design of a certain application. Priorities on the use of resources during a major emergency will to a large extent depend on the structure and general risk picture of the application.

- The integration platform will sort out the information that at any time is most relevant to the decision maker. It would be an "overkill" to display to the decision maker all available information.

- The general Environment Information System provides all relevant information on the past, present and future state of the environment. This also includes sensors for monitoring of radioactivity in water. Another feature is that of quick deployment of monitoring on land and at sea by helicopters and/or airplanes.

- Risk may develop differently from that predicted by the advance risk analysis. Therefore risk analyses will be made as the major emergency develops. This forms the basis for priorities on the use of resources to mitigate the consequences of the crisis.

- MEMbrain provides a system for continual monitoring of the situation associated with the application in question. The system is therefore in daily use for monitoring, as well as during the aftermath of a crisis.

- Training and message management are parts of MEMbrain. Experience shows that it is important to transmit messages in a way such that the recipient understands them in the same way as the sender.

- MEMbrain has plans for computerized preparedness plans.

The computerization gives quick, easy and dependable access to such plans. So far preparedness plans exist only in book form.

2. The MEMbrain EIS

The full MEMbrain EIS system deals with:

- Dispersion of pollutants over long and short distances.
- Monitoring of atmospheric radioactivity, toxic and dangerous gasses and traditional meteorological variables.
- Oceanographic information
- Dispersion of pollutants in water over long and short distances.
- Monitoring in water of:
  - Radioactivity
  - Traditional oceanographic variables
  - Algae and suspended matter
  - Oxygen
  - Nutrients.

In this paper we focus on the part of EIS dealing with data from the ocean.

The Use of SEAWATCH in MEMbrain EIS

SEAWATCH is a marine monitoring and forecasting system designed and developed by OCEANOR. After a development period of three years SEAWATCH has become a technically advanced marine monitoring system ready to serve different purposes for real-time data and information from the marine environment.

In MEMbrain parts of the SEAWATCH technology is further developed. This applies especially to:

- Self deployable ocean moorings
- In-situ radioactivity measurements by buoys.
- Accommodate numerical models to facilitate backtracking of the source of potential pollution.
- Improve and simplify all user interfaces.
- Fit EIS system architecture to the general EUREKA MEMbrain integration platform and other products like the Message Management System..

Self Deployable Ocean Moorings

Major Emergencies may take place in areas where no monitoring of the environment is made. The need for data will be very urgent thereby disqualifying deployment from ships. The alternatives are deployment from helicopter or aircraft. Also, the ME may cause radiation doses higher than what is acceptable to humans. This problem can also by solved by deployment from the air. Using parachutes, monitoring equipment can also be dropped over land. Such technology is described [Berteaux, Kery and Walden (1992)]. Further developments are under way at Woods Hole Oceanographic Institution. The first air drop was made by OCEANOR in December 1993, and further work is in progress.

Fig. 1 below shows one prototype of air deployable radioactivity buoy developed by OCEANOR.

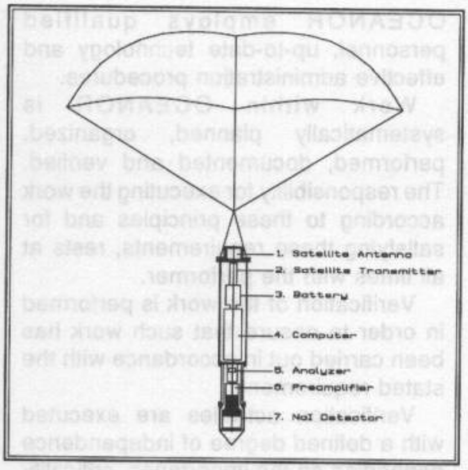

Fig. 1

In Situ Measurement by Buoy of Nuclear Radiation

An example of instruments that are ruggedized to meet the impacts during deployment from aircraft is the radioactivity sensor. The sensor itself is a 3"x3" NaI detector that produces a γ-radiation spectrum. Thereby the different nuclides present can be detected.

To our knowledge no other sensor with similar sensitivity and detection limit is available for serving this task.

A NaI detector is a sensor developed for laboratory use and/or very careful handling in the field. OCEANOR's development has been related to:

- Housing which protects the sensor from shocks and temperature gradients.
- Lowering the detection threshold.
- Reducing power consumption.
- Processor hardware and software to produce a 1024 channel spectrum.
- Linking to ARGOS and Inmarsat satellite telemetry.

Fig. 2 shows a logarithmic spectrum from a situation at 180 Bq/m^3.

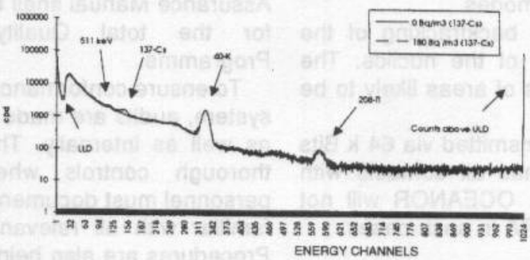

Fig. 2 Logarithmic γ spectrum at 180 Bq/m^3 Ref. 2. cpd=counts per day, BKG=background radiation

3. SEAWATCH Modelling

An important element of SEAWATCH-Europe is the data control, analysis, storage, operational use of numerical models and forecasting. Data received at the SEAWATCH-Europe Center in Trondheim are subject to a data control before it is released for further dissemination and stored in the database. The next step is to prepare forecasts. This is done based on buoy data an supplementary information such as weather bulletins, weather maps, results from numerical models and other data sources. Types of forecasts are algae blooming, currents during marine operations, water level, the haline structure in the water masses and water temperature. Among the users of these forecast are State Pollution Control Authorities and the offshore industry.

During ME situations a special service is initiated, depending on the extent and type of emergency.

This can be illustrated by a nuclear radiation emergency. If unnatural levels are measured, the National Radiation Protection Authority (NRPA) is immediately notified following a thorough control of the data. Then a system of numerical models are run in both hindcast and forecast modes.

The hindcast is for backtracking of the most probable source of the nuclids. The forecast is for warnings of areas likely to be hit by the pollutants.

All information is transmitted via 64 k Bits line to NRPA which has all contacts with media and the public. OCEANOR will not inform others than NRPA in such cases.

4. Data Quality Control

To achieve the required level of quality and to ensure a minimum risk exposure from our activities to personnel and environment, OCEANOR employs qualified personnel, up-to-date technology and effective administration procedures.

Work within OCEANOR is systematically planned, organized, performed, documented and verified. The responsibility for executing the work according to these principles and for satisfying these requirements, rests at all times with the performer.

Verification of the work is performed in order to ensure that such work has been carried out in accordance with the stated requirements.

Verification activities are executed with a defined degree of independence depending on the importance, criticality and complexity of the work in question.

To accomplish this, the OCEANOR Quality Assurance System is developed and implemented throughout the company in order to meet the requirements of NS-ISO 9001. All department managers are responsible for the development, implementation and maintenance of Quality Assurance Program applicable to their respective areas. The OCEANOR Quality Assurance Manual shall form the basis for the total Quality Assurance Programme.

To ensure conformance with the QA-system, audits are made by customers as well as internally. These are very thorough controls whereby project personnel must document that they are familiar with all relevant procedures. Procedures are also being checked.

Working with oceanographic measurements, it is difficult to be completely convinced that the data are 100% correct. The only way in which a customer can be convinced on data quality is by demonstrating for him/her the way data are taken. This means a demonstration of all procedures that the customer is interested in, and a documentation of the fact that all personnel are fully familiar with their procedures and follow them when carrying out their work. This approach, together with quality controls (QC), form the background for assuring that the data holds a certain quality. The quality level of the SEAWATCH data is that of the international standard ISO 9001.

In addition, the extent to which data measured by the buoys are in accordance with parameters obtained by analysis of water samples taken during deployment and recovery of buoys, can be demonstrated for the customer.

As per 15 December 1993 OCEANOR is operating 16 buoys - all not being the SEAWATCH type - in the Barents Sea, North Sea Skagerrak, offshore the Netherlands, Bay of Thailand and the Pacific Ocean.

Onboard all these buoys data are processed hourly, thereby producing parameters for transmission via the ARGOS satellite system. The data is continually stored in OCEANOR's computer. The person in charge of the monitoring projects will normally, via terminals, take a quick look at the data to see that the situation is normal.

However, the main quality control takes place in the forecasting room of OCEANOR daily at 0830 hrs. To make the control there is always one biologist and one meteorologist/oceanographer present, the reason being that the data is of physical as well as biological nature.

The controls concentrate on items like:

- Buoy position
- Light transmittance and oxygen for detection of suspended matter or algae
- Current speed and direction
- Wind speed and direction
- Air temperature
- Air pressure
- Sea temperature also including profile
- T-S profile
- Radioactivity
- Sea surface salinity
- Wave heights and periods
- Wave directions
- Nutrients.

Weather maps - analyzed and in prognosis form - are available to the controllers. For the North Sea, also prognoses of surface currents and sea level by OCEANOR's 3-D model HYBOS are at hand.

The background for validating some of the data is as follows:

- Buoy position shall be within a certain distance of that of deployment.

- At the various sites it is known by experience after some time of measurement that the parameter values have a certain probable range.
- Wind speed and direction are assessed by comparison with weather maps. This also apply to air pressure and air temperature.
- Current speed and directions in the North Sea are compared to values calculated by HYBOS.

- Wind direction is in more than 95% of all cases parallel to that of the high frequent part of the wave spectrum. This correlation is so good that, without measuring wind, the wind direction can be considered as given by that of the high frequency part of the wave spectrum. Having access to weather maps, this is a good basis for controlling the buoy compass.

- When Field Department personnel deploy or service the buoys, CTD profiles are often taken along with water samples. These are also means by which the performance of some of the sensors are validated.

When the daily data controls uncover errors, the Field and Instrumentation Department and the project leader are immediately informed. This non-conformance is communicated in terms of a filled out error form. Action to correct errors in terms of service cruises is normally taken within one week. The actions taken are on a routine basis reported back to the data controllers.

Data Storage

The ARGOS transmitted data are stored using a data base. Case with buoy failure giving rise to missing or erratic data are marked with dummy variables. If only one data point is missing, a linear interpolation is made. This data base works as a backup for data recorded internally by the buoys, if the internal data recording fails, ARGOS telemetered data is used for replacement.

Work on an upgraded database is now under way. Here we will store information related to the data like

- Cruise reports
- Results from analysis of water samples taken during deployment and recovery of buoys
- Etc.

Customers can receive data directly from ARGOS or from OCEANOR's computer. It is only in the latter case they may access quality controlled data. Onboard recorded data or data reports based theron are of course also available to customers of the SEAWATCH-system.

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RESPONSE AND REMEDIAL ACTIONS FOR A LARGE AREA AFFECTED BY A ROAD TRANSPORTATION INCIDENT INVOLVING PHENOL

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ABSTRACT

This activity report intends to show the response and the serious consequences generated by a hazardous material incident involving phenol in a road transportation accident near São Paulo, Brazil, on December 7, 1992.

Since the carrier and the phenol manufacturer were not efficient in responding to the emergency, serious damages have been caused to the environment such as: a high rate of fish mortality in a nearby lagoon, contamination of a river 1,100 m from the scene of the incident and contamination of about 150 m of the roadside soil.

One year later, the remedial actions are continuing, since the phenol has infiltrated into the soil and the recommended maximum concentration has not been reached yet. Among others, the remedial actions taken by the carrier and the manufacturer include: blockage of the road drainage system, partial roadside soil removal, interruption of the use of the river as a water supply, usage of activated carbon for phenol adsorption to avoid lagoon contamination, aeration of the lagoon and phenol oxidation with hydrogen peroxide.

This report shows the responsibility of a polluter to respond to a hazardous material incident in an efficient way as well as the infrastructure of CETESB, the São Paulo Environmental Protection Agency, in dealing with this kind of emergency.

THE ACCIDENT

At 4:45 a.m. on December 7, 1992 CETESB, the Environmental Protection Agency for the State of São Paulo, was summoned by the Highway Department (DERSA) to respond to a hazardous material incident which had occurred during a road transportation of 27,780 liters (7,340 gal.) of molten phenol at km 31 of the Bandeirantes Highway near São Paulo.

The truck tank trailer turned over and 22,000liters (5,812 gal.) of phenol were spilled from the truck top loading/inspection port onto the roadside soil. Part of the spilled product had drained over 150 m (450 ft) of the roadside soil and had reached the road drainage system which, according to DERSA, drained directly into the Juquery River(1,100m/ 3,670 ft away), while another portion of phenol had infiltrated into the soil (Figure 1).

EMERGENCY RESPONSE

The CETESB emergency response team arrived at 6:00 a.m. and, along with the Fire and Highway Departments, made an initial evaluation of the incident in order to size up its consequences. During the inspection, it was observed, among other things, that:

- there were a lot of phenol pools on the roadside soil;
- there was a high level of phenol vapor in the atmosphere, measured by a gas detector;
- there were still about 10 ton of phenol inside the tank;
- part of the spilled product had already reached the road drainage system.

Therefore, the coordination group formed by CETESB and the Fire and Highway Departments took the following actions immediately:

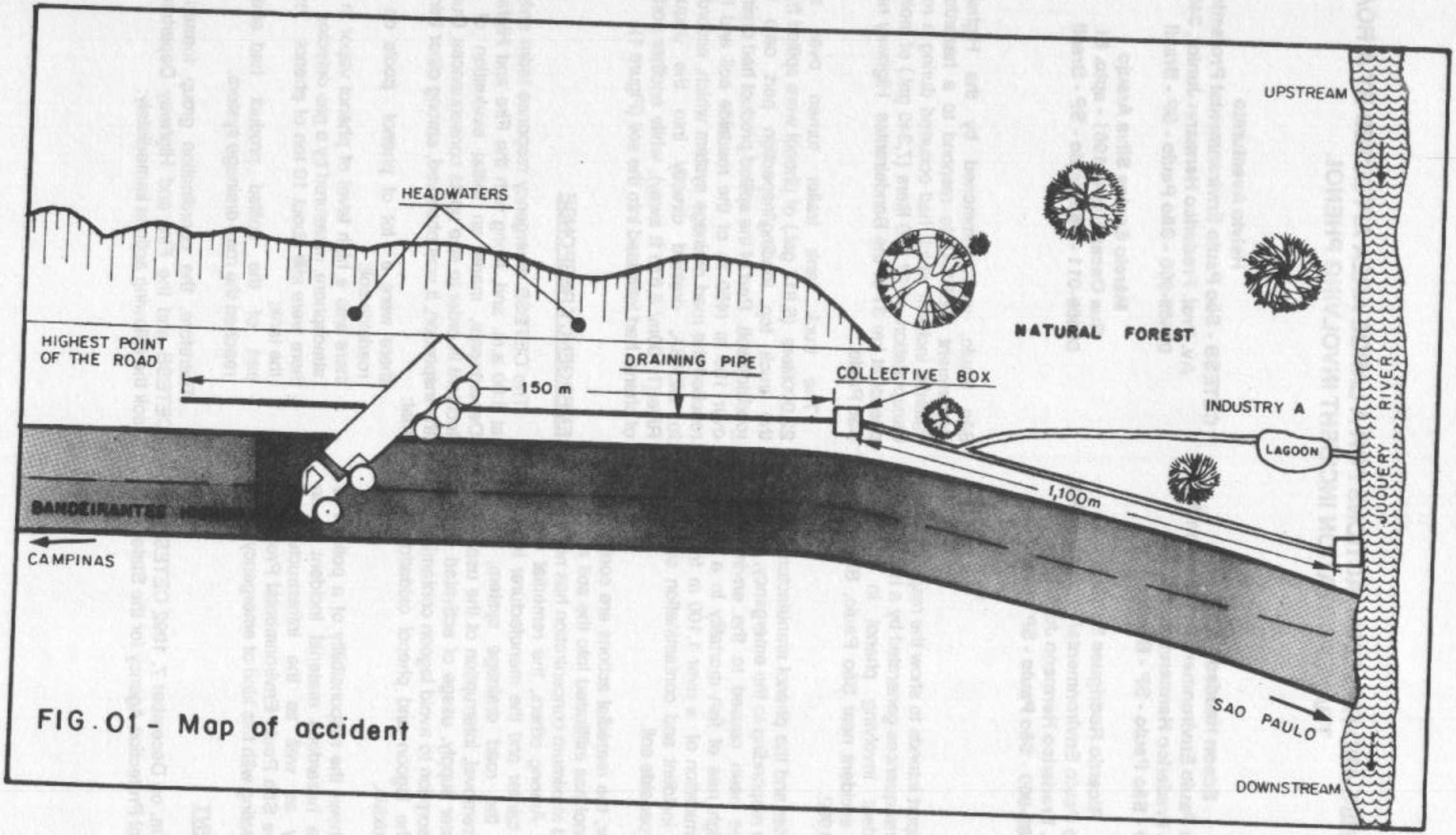

FIG. 01 - Map of accident

- construction of a sand dike around the collective box of the drainage system;
- contacting with the manufacturer and the carrier, requesting that they provide human and material resources to face the emergency, including trucks and pumps to recover the spilled product as well as to remove the contaminated soil;
- expansion of the initially isolated area;
- notifying people who lived near the Juquery River to make no use of the water until further notice.

The carrier arrived at 10:00 a.m. and after their initial evaluation, it became apparent that it would not be possible to transfer the product inside the damaged tank to another one because of the small quantity of phenol, about 8,000 kg (17,660 lb), the position of the tank and mainly because of their pump which was not the most adequate for that particular chemical.

The manufacturer contracted three vacuum trucks in order to remove the phenol contained in the tank as well as to recover the phenol pools on the soil. These vacuum trucks arrived at 12:00 p.m. and the transfer of the phenol from the damaged tank was carried out by the Fire Department personnel who had to wear fully encapsulating suits. It ended at 2:30 p.m. and about 7,200 kg (15,900 lb) of the phenol were recovered and used to make resins.

Simultaneously, the other two vacuum trucks were carrying out the recovery of the phenol pools spread over the roadside soil. In order to make this activity easier, water from the Fire Department truck was used to rinse the soil while suctioning off the chemical into the trucks. Eighteen thousands liters (4,755 gal.) of a 15% water/phenol solution were recovered which was treated as residual water at the manufacturing plant.

There was another task to be done, which was the removal of the contaminated soil. Despite the CETESB weather forecast about the possibility of rain, which would have complicated the emergency, the manufacturer and the carrier did not mobilize the required resources, so the Highway Department sent four trucks to transport the contaminated soil, but this number was insufficient. About 24 m3 (890 ft3) of residue were sent to the manufacturer and stored in plastic bags in drums for future disposal.

It is important to say that the layer which was removed was only 0.2 m deep and 60 m long, which was not nearly enough. Therefore, the coordination group decided to build two dikes in order to protect the collective box of the road drainage system from rain water carrying phenol.

Finishing the activities of that day, the damaged tank was righted, the affected area covered with a plastic sheet and the São Paulo Civil Defense released a bulletin notifying people to make no use of the Juquery River.

On the 9th, CETESB sampled the Juquery River water upstream and downstream from the point where the road drainage system emptied into it and the results (0.59 mg/L for both) showed the river contamination had occurred at another place, since the normal concentration in this river was 0.001mg/L, which is the maximum permitted by Brazilian law.

On the same day, an industry (here called A) located 1,200 m (4,000 ft) from the incident notified CETESB a high rate of fish mortality in its lagoon (about 500 carps), along with a strong phenol odor.

Only with this information and after a careful inspection of the natural forest existing between the spill and the industry A, was it possible to discover the actual path taken by the spilled product. After it reached the road drainage system, the phenol traveled to the industrial lagoon, which drains into the Juquery River. New samples were taken which confirmed the lagoon contamination (182 mg/L) and the way in which the Juquery River had been reached (Figure 1).

Despite CETESB's repeated requests to the manufacturer and the carrier to remove the contaminated soil, they only complied on December 10. Throughout that day, 60 m3 (2,222 ft3) of residue were removed and transported to the manufacturing plant. However, because of the rain on the 8th and 10th of December, the phenol infiltrated into the soil and therefore a greater depth of soil was contaminated and could not be subsequently removed, once this could have compromise the road structure.

SITE CHARACTERIZATION

The accident occurred at the foot of a hill where two headwaters are located. This water drops to on the roadside soil and after seeping through four meters, it reaches a draining pipe which carries the water to the road drainage collective box. This drainage system goes to the industrial lagoon and after that, to the Juquery River.

The roadside soil is formed, basically, of crushed rock which permits a high level of penetration in a reduced time span.

An investigation enabled the team to conclude that most of the spilled phenol infiltrated at the foot of the hill through the crushed rock. This investigation also showed that the underground water (40 m/133 ft deep) was not affected by the incident.

REMEDIAL MEASURES

Ten days after the incident, the phenol levels were still above the recommended limit. CETESB met with the manufacturer and the carrier and decided that the following actions should be taken:

- blockage of the road drainage system and removal of the headwaters that flow through the draining pipe;
- phenol oxidation with hydrogen peroxide;
- aeration of the industrial lagoon;
- usage of activated carbon for phenol adsorption before the lagoon.

Both companies committed themselves to aiding CETESB and on December 18 these measures were taken.

Thirty-two hundred liters (845 gal.) of hydrogen peroxide (120 vol. -35%) and 1,055 kg (2,329 lb) of ferrous sulfate for the phenol oxidation were used. Before it has been used, the phenol concentration was 200 mg/L against 1,240 mg/L after hydrogen peroxide application. Anyway, this high concentration has lasted only for a few hours.

On December 21, after a rainy night, the phenol concentration in the draining pipe reached around 1,200 mg/L again. Therefore, it meant that all the hydrogen peroxide has reacted with the phenol, and soil also, while another amount of phenol was carried out by the rain. This fact, explained why the phenol concentration had gone up to 1,240 mg/L after the hydrogen peroxide application and also the rain. For that reason, a new application was performed on December 22 and the results have been satisfactory as well.

On December 23, the manufacturer constructed a dike upstream of the industrial lagoon and cotton bags of activated carbon plus sand (2:1) were placed to percolate all the feeding water coming from the contaminated area to reduce phenol levels. It was possible to reduce the phenol concentration from 1,200 to 78 mg/L. This job was performed for 3 months and the use of the lagoon was liberated when the phenol concentration reached 0.004 mg/L.

A new hydrogen peroxide application was performed on December 30, but this time the roadside soil was revolved to make its infiltration into the soil easier. About 30 trenches were dug (1 meter/3 ft deep) for this purpose.

On December 31, the carrier installed a pump in the collective box of the road drainage system in order to remove full time the contaminated water, which was pumped into a tank truck.

Instead of another hydrogen peroxide application, which was expensive, the carrier and the manufacturer decided to use water to remove the phenol. A sample collected after the usage of water showed 1,370 mg/L of phenol. Later, hot water (90^{o}C - 194^{o}F) was used many times for this operation and the results were better.

On January 7, a pump was installed in the lagoon in order to aerate it.

By January 26, 500 m3 (18,520 ft3) of water had been removed from the drainage system collective box (which was blocked).

On January 28, the manufacturer asked CETESB for authorization to use foreign microorganisms (bacteria) in order to accelerate the roadside soil recuperation. However, CETESB did not agree with its use since they intended to use foreign microorganisms which could have been dangerous due to possible unknown effects on that habitat. CETESB sent them a proposal on bioremediation with local bacteria, but they rejected it (too lengthy and expensive).

Throughout February only a mixture of hot water and 10% sodium hydroxide was used to induce the solubilizing of the phenol and, consequently, its removal from the soil. It was ultimately recovered from the blocked collective box. By the end of February, the phenol concentration was 150 mg/L.

By the end of February, the 3 last samples from the Juquery River, showed that phenol concentration was less than 0.001 mg/L and the São

Paulo Civil Defense released a bulletin notifying that the Juquery River had already reached its normal phenol level and that, therefore, it could be used again by the population.

To reduce the volume of water pumped out, the carrier and the manufacturer have been recycling the water from the collective box and reutilizing it to rinse the roadside soil.

On October 5, new samples were taken which confirmed that both the Juquery River and the industrial lagoon were not contaminated anymore (<0.001 mg/L). However, the phenol concentration in the roadside soil was about 3 mg/L, which still was above the recommended maximum limit.

Thirteen months after the incident, the phenol in the roadside soil has been reduced to 0.01 mg/L, which leads us to believe that the activities there are about to be ceased.

POLLUTER OBLIGATIONS

Responding to a hazardous material incident is not as simple as it might appear. It is not enough to have extra truck tank trailers and people as resources. It is necessary to have a trained team equipped with adequate protective gear, a rescue team and resources such as pumps which can be mobilized at any time for any location. The Brazilian law for road transportation of hazardous materials requires this.

This accident became worse as the carrier response was not efficient. They were slow and poorly equipped for this situation.

The consequences to the environment were serious. The fish mortality, the roadside soil contamination and the interruption of the use of the river as a water supply, among other things, illustrate the graveness.

The manufacturer estimates that 13,880 liters (3,677 gal.) of phenol had remained infiltrated in the soil after the incident.

The expenditures of all entities involved were enormous. CETESB performed hundreds of laboratory analyses. Its technical staff was mobilized for hundreds of hours. The carrier kept 3 people working 24 hours per day for 2 months to remove the water containing phenol from the draining pipe. They replaced 500 carps in the industrial lagoon as well.

About 113 ton (250,000 lb) of all residue removed will be incinerated in a Cement Company's furnace. It will cost US$ 50,000.00. The total expenses have already reached US$ 150,000.00 and it has been supported by the carrier.

It would certainly have been less tedious if the carrier and the manufacturer had contracted some trucks to transport the contaminated soil as soon as the accident occurred and before it rained.

This sad occurrence has become an example to other carriers which, we hope, will be adequately preparing themselves for future emergencies.

CETESB'S INFRASTRUCTURE FOR ENVIRONMENTAL ACCIDENT ASSISTANCE

Since 1978, CETESB has been acting on accidental emissions of hazardous materials generated either in the industry or during transportation or storage in São Paulo State. CETESB has been responding to an annual average of 200 incidents. This number does not represent all the accidents that occurred in São Paulo State, but rather only those in which CETESB was involved. Most of these accidents occur on the road when hazardous materials are in transit and most of them involve flammable liquids and are due to human error.

The area responsible for these activities is the "Divisão de Tecnologia de Riscos Ambientais" (Environmental Risk Technology Division), which is divided into two "Sectors": the "Setor de Operações de Emergência" (Emergency Operation Sector) and the "Setor de Análise de Riscos" (Risk Analysis Sector). This Division permits the handling of both preventive and corrective aspects of accidental pollution.

CETESB keeps a four-person intervention team on permanent stand-by for emergency response to incidents in Sao Paulo State compound by namely: one coordinator, one chemist, one engineer or biologist and one technician (driver).

To contact this team, CETESB maintains at its headquarters an assistance center to attend to the population's calls to orientate the community and other entities on problems related to accidental pollution and to serve as a base for the stand-by intervention team.

Furthermore, CETESB has developed and implemented some data bases among which are the Data Bank on Chemical Products, presently registering 850 substances, and the Environmental Accident Data Bank (CADAC), from which the statistics mentioned above have been extracted.

For accidents involving chemical products, CETESB counts on a properly equipped Mobile Unit for Environmental Accident Assistance, which contains, among other things, a communication system, chemical protective clothing, field analysis kits, combustible gas indicator, oxygen indicator, gas detector, pH indicator, SCBA and others.

Due to the increase in the number of solicitations that CETESB receives from the population, industries and other governmental offices, it is possible to say that it is well-structured to respond to accidents generated by hazardous substances. However, it is worth stressing that, because of the dynamics with which an accident happens or develops, there is a need for the implementation of a program of information exchange and technical renewal with other organizations, in order to obtain a broader knowledge. This would promote a constant upgrading of the CETESB staff.

SÃO PAULO STATE'S ENVIRONMENTAL ACCIDENT ASSISTANCE SYSTEM

The great incidence of environmental accidents involving chemical products in the last years, made obvious the need to adopt preventive and corrective measures aiming both to diminish the probability of occurrence of such episodes and to quickly mobilize all participating agencies.

In 1986, the "Coordenadoria Estadual de Defesa Civil" - CEDEC (Civil Defense State Coordination) implemented an "Integrated Communication System" that links around thirty agencies, among which may be highlighted: the CEDEC, the Fire Department, the Highway Patrol, the Military Police, the São Paulo County Administration, CETESB, the State Water and Sewage Company, the Brazilian Chemical Manufacturers' Association, the National Association of Cargo Transportation Companies, the Traffic Engineering Company, the Civil Defense Municipal Commission, etc. It is a four-digit telephone number which is connected with a network of operational centers, making contact and mobilizations in emergency situations. It is operative 24 hours a day, 365 days per year.

Because most environmental accidents happen in São Paulo County and during road transportation, the agencies above elaborated an "Emergency Plan for Accident Assistance in Road Transportation of Hazardous Materials in São Paulo County". In this plan, the attributions and responsibilities of the integrating agencies are defined. Furthermore, the handling of issues referring to road transportation in São Paulo County includes the following activities:

- preparation, implementation and publicizing of the Emergency Assistance Plan;
- survey and registration of material resources;
- classification criteria for substances that are potentially dangerous for road transportation;
- execution of theoretical and practical training programs for the staff;
- preparation of studies for the definition of alternative routes and timetables for hazardous materials transportation in São Paulo County.

In addition, it establishes that the field coordination during an emergency is the responsibility of the Fire Department, CETESB and the Traffic Department, while the remaining agencies must give support when required.

This plan has just been implemented and, at this moment, it is under tests and evaluation.

Therefore, the need for permanent improvement of assistance systems for emergency situations caused by chemical product incident is clear. Quick and efficient response when these events occur, as well as a good integration among all involved agencies, are the means to guarantee security to the population and to the environment.

A CONCEPTUAL ROLE FOR MODERN INFORMATION SYSTEMS IN MANAGING EMERGENCIES IN ELECTRICAL POWER NETWORKS

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ABSTRACT

The subject paper presents a conceptual scheme for data acquisition, analysis and diagnosis of electric power system disturbances utilizing the high-speed capability of supercomputers. The scheme applies three major parts, namely:

1 -A Supercomputer architecture provided with a data base base management (DBM) system, and placed atthe energy system main(highest control hierarchy) center.

ii -A modern SCADA(supervisory cotrol and data acquisition) system linking the main center with remote (Slave)Stations(power stations or substations)which are provided with RTUS and other elements.

iii -A high speed communication technology for data transmission between the main and the slave centers.

The paper provides a rational for decision of the most appropriate technology among:

- SIMD(sigle instruction streammultiple data stream) vector machine or MIND (multiple instruction streammultiple data stream) multicomputer system.
- parallel vector machines with single and multiple pipelines.
- The fastest known communication technologies, namely; coaxial fiber-optic cables, or satellite radio system.

At last, the paper draws recommendations for the most promising technologies, from author's point of view.

1- Power Utilities and systems

A power system is always subject to unforeseen disturbances of different kinds covering a wide spectrum raging from small kicks in voltage or frequency up to hazardous accidents leading to partial or even complete blackouts Identification of such disturbances with the appropiate apeed,e.g. on real time base, will undoubtedly contribute to power system service continuity, reliability and hence to the adtional or macroeconomy. Before proceeding further in the subject of power systems disturbances, it is worth noting the main differences between one power utility or system and another. These vary in many respects like:

a) Main system Features: power systems vary according to size(MW interconnection) and geographical coverage.
b) Main structure, i,e,if a utility is centrally situated within a much larger interconnection, or either a utility not interconnected with neighbours or by far the largest partener in an interconnection.
c) Network Sub-Classification i.e.a utility having a multiply meshed transmission system with dispersed generation and demend, or a utility having a lightly meshed transmission system with stability or voltage rather than themal limits.
d) Control structures implemented in various utilites may be classified into six levels:
   - SC: Central or coordination center for an international interconnection
   - NC: National Control Center of a country
   - MC:Main Dispatch control center of utility or a group of utilities not covering a whole nation

- RC: Regional Control Center
- AC: Area Control Center

2- A Concept For System Control Scheme

SCADA equipment should be installed at system control center (which may be SC, NC or MC mentioned above, whichever is highest level available in the system). These may include:-

a) A supercomputer architecture for numerical applications. This can be based on either of two major principles;
   - SIMD vector machine
   or - MIMD multicomputer system.

   The supercomputer architecture should also be designed for reception of the high rate data acquisition, besides other control applications.

b) The system control center should also inrolve the routine equipment like, e.g. two console-mounted master terminals (a main and a stand by), a common console containing a remote (or slave) station simulator, a main-to-stand by processor switch-over, and a station indicator and control panel of uninterruptible power supply (UPS). These besides other I/O devices like multi-colour visual display units (VDUs) with keyboards, chart recorders (dual or multi-pen), a test RTU, printers disk drives (for each processor), ... etc.

3- Conceptiual System's Functions

These may be classified into normal, and additional duties. The latter in turn is subdivided into permanent and occasional.

a) Normal Duties: The function of the system during normal, or non-drastic disturbances conditions is described as follows:-

i - Supervisory Control, Commands can be sent from the SCC (System Control Center) to slave (or remote) station units to open or close circuit beakers, raise or lower taps on voltage regulators or transformers or perform any remote function that can be controlled by one or a series of binary switch openings or closings. It may also include load-shedding feature programmed to operate selected feeders.

ii- Data Acquisition; RTUs accept and transmit to the SCC binary indications both permanent and fleeting, analog values, and pulse accumulator indication. This allows data to be collected on circuit breaker status, and operation, voltage, current, KW KVAR, and KWH.

iii- Monitoring: At the SCC console, the system is to be configured to poll all remote (slave) stations sequentially for data.

IV- Status Monitoring: The displayed status of field devices is refreshed periodically by the master interrogates all RTUs in sequence. Status is stored in the master station's data base (DB), and may be called up for interactive display on to independent CRT/Keyboard operator's consoles.

V- Analog Monitoring: Analog imputs are digitized by the RTUs and reported to the master station. This latter provides automatic scaling of reported values into engineering units

VI- Pulse Accumulation: Pulse imputs are accumulated at each RTU, and are frozen and read hourly by the master station.

VII- Display and Record: At the SCC, the outputs may be presented by hardware devices in the operating console like audible alarms in case of uncommanded changes of system state, visual display units to read data on command, besides reading real time and historical data, Printers which are to be interconnected to the processor and the VDUs, thus logging data reports events in a hardcopy form, a switch to transfer from main to standby processor, a mimic simulator (for slave substations) should be provided to permit the operator manual simulation of tast RTU parameters.

VIII- Θperational Control: At the VDU keyboard, audile alarms will be acknowledged and supervisory - control commands issued as required In sddition to real rime operations the keyboard serves as the user's point of entry for initial system configuration and for DB Programming.

Ix - RTU/Master Communucation: The for mat for communication is :

1-Master interrogation, RTU(slave) response. The master interrogates a giver slave(RTU), then waits a predetermined interval for a response if response received then function preceeds to next RTU.

2-When a potential disturbance occurs, an informal signal is dispatched to the master station(SCC) with the logical scale describing the main features of the disturbance.

3-The master station(SCC)dispatches all RTUS; at each potential change in system's configuration or status; computed values of equivalent e.m.fs agles and impedances, of the system, reflected at eash station bus.

b- Additional Duties: The technology of power system automation assistance of computers is progressing rapidly. Inspite of this fact, still there is much to be done, especially for diagnosis of disturbances on a realtime base. Actually, this latter idea is the base of our proposal to introduce the supercomputer and this to benefit from its capability in this respect. The function of the supercomputer architecture; which should be situated at SCC; may subdivided into permanent, and occasional(fleeting duties).

b-i) permanent Duties, i.e., duties to be performed irrespective of existence of disturbances. These include computation of :-

- Equivalent system impedanves(or admittances)reflected at each RTU bus. This covers, positive and zero sequence values.
- Voltage angle at each bus, referred to swing bus.

The above values should be updated at each potential change in system topology, generation value or mix, or damand. The above mentioned be issued to all slave stations. Another duty is to update computations for the moust probable types of disturbances, generate corresponding logical scales which should be classified according to type andloca tion(nearst bus) stored.

b-ii) Occasional Duties i.e., when need calls, mamely after drastic disturbbances in the system. These duties are discribed as follows(with reference to Fig"1") *

1-The SCC collects all logical scales coming from the different stations.

2- The supercomputer sorts these logical scales(L.S) to find out the nearest bus to disturbance

3-It compares; for the nearst bus to disturits computed and observed L.S if this results in 100% coincidence, then the disturbance now is defined; typewise and locationwise. Hence corresponding countermeasures should issued to SCC and slave station.

4-If the 100% coincidence is not realized, then the program should should select the three programs realizing the highest % age of cioncidence, and recompute them; with fresh data (updated) and hence repeat the checking for concidence's procedure. If the 100% coincidence is realized, then repeat process. Otherwise a report should be generated issued to SCC and slave stations. This report should brief:

- The most probable type of disturbance (the above mentioned three programs in descending ordrder of % age of coincidence), and nearest bus to it

*C.M, 3RP designates countermeasures and report of 3 programs respectively.

The corresponding countermeasures versions.

4- A Supercomputer at SCC. Is It a Necessity?

It is well known fact that supercomputers obtain their performance from two contributing factors. Firstly they operate at the highest posible speed technology can provide.

Secondly, additional performance is gained through parallel processing.

If we inspect the conceptual system's function in Sec. (3), we can easily reveal that, to perform both the permanent and occasional duties, the only feasible solution will be the supercomputer with its associated ultra-high processing speed.

5- Software Problems and Adoption of Supercomputer Mode

An algorithm may be generally defined as a partial order of operations, the partial order being determined by the data dependencies between the operations. We call the parallelism of an algorithm explicit if the data dependencies are well - defined by the nature of the data types to be processed, and consequently are known a priori. We call the parallelism implicit if it is not a priori known, but must be determined through data dependence analysis.
Unlike implicit parallelism, explicit parallelism can be exploited with minimal control overhead, using either one of the two strategies known as:-

- The SIMD mode of operation
- The MIMD mode of operation

The decision between the two architectural forms involves a tradeoff between the high cost effectiveness of SIMD mode and the higher flexibility of MIMD mode.

Electric power system application packages are mostly written in FORTRAN. Creating, or even rewriting, these packages in 3- dimensional form will be very laborious task, and needs the cooperation between interested institutes and software houses all over the world.

Historically the parallel processing user has been a rather knowledgeable scientist or engineer who is willing to assume the burden of creating application programs, using rudimentary environments. Detailed architectural and operating system knowledge as well as the intricate ability to manually map parallel algorithms onto a virtual parallel architecture are some of the hurdles such users had to overcome.

But there is a questionnaire that may arise here, that is "which type of supercomputer shall we start with; single pipeline or multiple - pipeline vector machines?

Before answering this, we may cast some light upon programming both types of machines.

- Programming of single pipeline vector machines, usually is carried out in FORTRAN. A number of vectorizing compilers have been developed which map the inner loops of conventional, FORTRAN programs onto the vector operations of the machine.
  The conditons under which such a mapping is possible and the techniques involved have become a well - understood topic.
- Multipipeline vector machines are presently programmed in a multitasking manner. Typically a task is a part of a program that can be run in parallel with some other parts of the program. The work to be done is partitioned into at least as many tasks, or processes; as there are pipelines. The system then maintains a task queue to which an unoccupied pipeline can go in order to find a task to execute.

To conclude this section, one can come to the concluding remarks:-

i - Most of power system disturbances analysis programs are based on linearized models. With this fact in mind, these programs may be considered of the explicit type or in other words, data dependencies are well defined by the nature of the data types to be processed.

ii- In the 1st stages; i.e during the first few years, the power engineers should be involved with creating or even rewriting power packages for parallel processing machines, so it may be wise to assume a SIMD vector machine operating with a few number e.g. up to 4 of pipeline processors

iii- The application programmer is assume to be a knowledgeable system programmer capable of using low level multitasking tools.

6- Adoption of Communication Technology

A wide variety of communication techniques have been investigated to make suc real-time automation possible. 9 potential technologies fall into 4 groups:-

i- Physically connected media, including wire lines, coaxial cable and fiber-optic cable.

ii- Power-line media, including distribution line carrier communication and power frequency communication.

iii- Electromagnetic propagation media, including UHF/VHF radio, AM/VHF radio, and spread spectrum Satellite radio.

IV- Common - carrier media, primarily telephone company lines.

Needless to say, that the highest feasible speed for data transimission is a very essential prerequisite for the success of our proposed scheme.

7- Conclusion and Recommendations

Before concluding this paper, we can summarize our proposals and findings as follows:-

For fast diagnosis, and hence taking the appropriate contermeasures, of power system's disturbances, the following developments are proposed:-

i - Utilization of the high - speed capability of parallel processors. In this respect, we propose the SIMD vector machine, with a few number of pipelines (e.g from 2 to 4), during the early stage of conversion from 2 to 3 dimensional programming. The SIMD computer should be placed in the main control Center (SCC), and should be provided with a power system data base management (DBM) system.

ii- To convert, or create 3 dimensional package, we may advise that the application progrmmer be knowledgeable system programmer capable of using low level multitasking tools.

iii- Beside provision of a modern SCADA system linking the system control center (SCC) with slave, or remote stations, a high speed communication technology should be adopted. We recommend that it may be one of the three variants, namely, coaxial, fiber-optic cables, or Satellite radio. Adoption of any needs a techno-economical feasibility study for each individual case.

IV- A new topic "EGIPT" is recommended to be widely opened for investigators for development.
This topic will be mainly in terested in quantitative evaluation of main features of power system's disturbances. These features are integrated into one of predefined categories, and hence a logical scale (an abstract vector) can be compiled. Observed (unknown type of disturbance) and computed (known type of disturbance) logical scales for each slave station are compared, and hence the type of the disturbance can be deduced.

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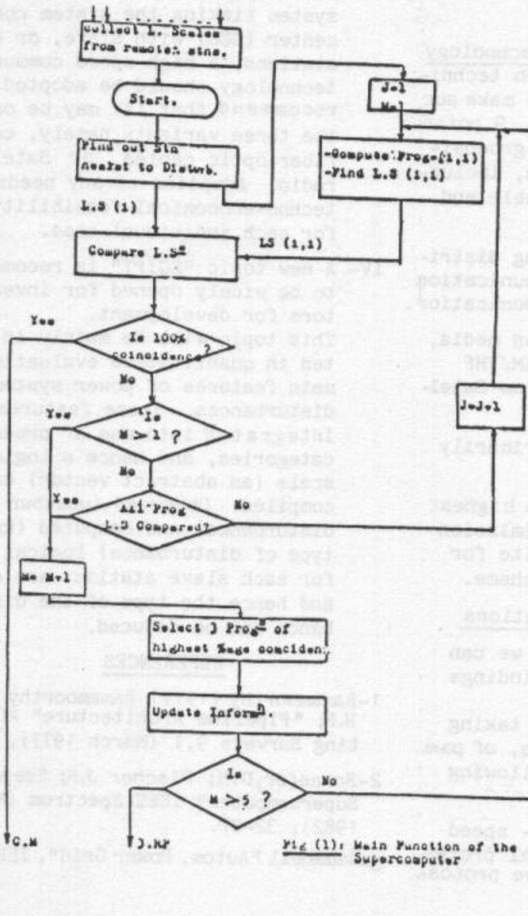

Fig (1): Main Function of the Supercomputer

RESEARCH AND APPLICATIONS

THE ALL-HAZARD SITUATION ASSESSMENT PROTOTYPE

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ABSTRACT

The Federal Emergency Management Agency has established its vision for the future. A key element of the new direction for the Agency is to ensure that Governments and private organizations have proven effective plans, necessary resources, and rigorous training for disaster response.

Specifically FEMA has established the following goals that are pertinent to this direction:

To create an emergency management partnership with other Federal agencies, state and local governments, volunteer organizations, and the private sector.

To establish, in concert with FEMA's partners, a national emergency management system that is comprehensive, risk-based, and all-hazards in approach.

To provide rapid and effective response to any disaster, a comprehensive situation assessment capability is required.

If FEMA is successful in achieving these goals, decision making in support of disasters will have access to information on estimated and assessed effects of an emergency event. Thus, situation assessment can provide support for preparedness, response, recovery, and mitigation.

This situation assessment capability is being achieved through the All-Hazard Situation Assessment Prototype (ASAP). This system combines models and databases in a Geographic Information System (GIS) which allows the estimation and assessment of the effects of natural and technological disasters. Currently, the ASAP is operational at Headquarters FEMA for hurricanes. In prototype, the ASAP includes floods, storm surges, chemical spills and releases, earthquakes, urban and wildland fires, and chemical releases. These capabilities will be made operational at Hq FEMA in the immediate future.

The following discussion will describe how the system works, the models that have been incorporated into ASAP; the databases that have been installed; and the applications of the GIS. In concert, these processes will enable FEMA to estimate the extent of damage and the population at risk from these natural and technological disasters.

1. Introduction

Responding to the criticism following Hurricane Andrew the Federal Emergency Management Agency instituted the ASAP. This initiative was undertaken by FEMA in response to Congressional recognition that the Nation must be better prepared to respond to natural disasters. As a result ASAP was initiated to acquire the software, computer hardware, and databases that would allow FEMA to estimate the potential damage to housing, businesses, and other resources from natural and technological emergencies.

The steps which are necessary for complete damage estimation and assessment are: model development; message receipt; analysis; and product generation. For example to estimate the damage from hurricanes, Headquarters FEMA receives messages from the National Hurricane Center transmitted by the Weather Service's Family of Services. These message are automatically processed to provide input to models that estimate the extent of potential damage. The resulting regions of estimated damage, "damage bands", are input to the GIS. Already stored in the GIS are databases that locate and describe the population and housing as well as a plethora of facilities, resources and assets. The GIS allows the emergency managers to intersect the damage bands with databases in order to determine the assets and population at risk.

2.0 HURRICANES

The ASAP is developing the capability to estimate in real-time the civil resources and population at risk from threatening hurricanes. This system provides sufficient lead time to allow emergency planning, readiness actions, and prepositioning of appropriate types and amounts of relief supplies.

The hurricane damage and at-risk population estimation module automatically reads the National Hurricane Center's Maritime Advisory Messages using the National Weather Service's Family of Services. The message is automatically parsed for current and forecast hurricane characteristics, e.g., current position, maximum wind speed, forecast positions, radii of wind speeds.

Using existing analytical techniques, the module generates complete wind profiles (wind speed vs. distance from storm center) for the current and forecast positions. The module adjusts the profile such that the gust velocity is the maximum wind speed, not the sustaining one-minute winds. These wind profiles are converted to dynamic pressures. Accepted structural response modeling techniques have been incorporated for determining the susceptibility of approximately 20 different structural types to the hurricane's dynamic pressure. Vulnerability criteria show the threshold dynamic pressures needed to cause severe, moderate, and light damage. The regions on the ground for severe, moderate, and light damage to each of the different structural types are calculated for the current position and each of the forecast positions. The damage typically represent a seventy-two hour forecast of potential damage.

The damage bands have been integrated with the ARC/INFO Geographic Information System (GIS) and numerous databases created by the Census Bureau and U.S. Departments and Agencies. Business databases are also included. Using automated, integrated system of models, databases, and GIS, the hurricane's damage potential to resources and assets as well as population at-risk can be anticipated.

A Predeployment Report automatically calculates the amount of relief support that will be required based on the estimated damage. With this information the sources of the needed support and the logistics required for prepositioning can be identified.

The initial operational capability of the hurricane damage estimation system was announced on June 1 1993. The system was in place for Hurricane Emily and proved to be completely functional for FEMA personnel utilization. Estimations of damage to residences based on the forecasts proved to be acceptably close to published damage assessments.

The on-going development activities include incorporating tidal surge damage estimations using the National Weather Service's Maximum Envelope of Water (MEOW) contours and best available digital elevation models (DEMS). In addition, hurricane track uncertainties are being added to the track information promulgated by the NWS in the Maritime Advisory Messages. Additional work on the structural response models is continuing particularly with attention to validation.

3.0 FLOODS

Responding to the immediate real-time demands of the Mid-West flood crisis situation the ASAP was able to provide valuable information to FEMA regarding the extent of flood damage. At the direction of the FEMA program manager the software developers provided the necessary set of techniques that would allow FEMA to determine the population and resources at risk due to the flood conditions.

In an effort to obtain more comprehensive information on the extent of the river flooding, FEMA initiated an investigation to determine if the NOAA satellites (NOAA 9, 10, 11, 12) could quickly determine the extent of areas flooded using AVHRR imagery. With this information, FEMA could then estimate the resources and assets and the number of people, houses and businesses at risk. FEMA was able to apply this technology because of its acquisition of a AVHRR ground station anticipating its use in a variety of disaster situations. The feasibility of using the NOAA satellites in this way had been demonstrated very early in the ASAP program during Arizona floods but had never been fully tested.

FEMA assembled a team of experts from the fields of satellite imagery, computers and geographic information systems (GIS) and put them to work on the problem. What was needed was to incorporate AVHRR images into the ARC/INFO GIS so that the data extracted from the satellite image could be combined with a multitude of databases.

The NOAA satellites are used for meteorological research and produce multi-spectral imagery with a maximum resolution of about 1.1 km. There are currently four satellites broadcasting useful data, and each is able to view a particular area about twice a day. The satellites have the advantages of a wide area of view (approximately two-thirds of the continental US. in one pass) and frequent revisit time, but have a relatively coarse resolution when compared to satellites such as Landsat or SPOT.

The first task was to develop software to determine which areas of the image represented water. This process is called classifying. The software used a variety of techniques to classify each pixel in the image as water, land, cloud or cloud shadow. Since each image is 2048 pixels wide and up to 5000 pixels high and covers 2/3 of the United States, the software would examine a user-selected sub-image which was 512 pixels wide by 512 pixels high.

Next, the software needed to determine the exact ground location of each pixel in the image was adapted. This process is called the image navigation. The software uses a set of complex calculations based on the last known position of the satellite to do the navigation. Outlines of the non-flooded river locations where overlaid on the satellite image to check for the accuracy of the image navigation.

If the river outlines did not line up correctly with the actual locations of the rivers in the image, the navigation was adjusted until the river outlines lined up on top of the rivers in the image.

The software would then transfer the locations of only those image pixels classified as being water to the ARC/INFO GIS.

When the AVHRR data had been successfully processed, the next step was to integrate the information into the ARC/INFO GIS. Polygons representing the extent of the flooding were generated from the point data developed from the image. These polygons were intersected with population and housing and other resource information to produce estimates of flood damage.

4.0 EARTHQUAKES

Experience has shown that in the time period immediately after an earthquake, emergency managers do not know the extent of damage due to broken lines of communication. Thus, responding to the damage and relief requirements of the disaster are often lagging. To improve this situation, Hq FEMA has adapted the USGS model developed by Jack Evernden.

The Evernden model is a collection of computer programs and databases for the calculation and display of various aspects of earthquake-induced ground motion. The model was developed and validated by J.F. Evernden of the National Earthquake Information Center (NEIC) of the United States Geological Survey (USGS). It is intended for the quick assessment of the effects of an earthquake to aid the delivery of fast, efficient, and effective disaster relief.

The model predicts only the ground motion due to shaking. Liquefaction and slumping are not treated by the model. For an earthquake occurring at a specified site, the model can calculate and map the resulting intensity of the event (on the Modified Mercalli Intensity [MMI] scale), the actual ground movement (in terms of its velocity, acceleration, and displacement), and the percent of buildings damaged for a few different building types.

The input parameters and data bases collectively describe the instigating fault rupture, the local ground condition, and the desired type of output. The outputs are maps displaying various ground motion parameters. Further, the value of the ground motion parameter at a particular lat/lon on the map may be determined.

estimation in near real-time of the extent of damage from earthquakes FEMA adopted the USGS model developed by Jack Evernden.

The Evernden model requires a minimum of initial conditions, e.g., the earthquake's epicenter location, magnitude. In addition the model requires geologic information (rock type). When merged with a geographic information system and the resource, population, and housing database, the emergency manager can quickly estimate damage and anticipate relief requirements.

During the recent Los Angeles earthquake, FEMA was able to run the USGS model shortly after the quake struck using information from the USGS National Earthquake Information Center. Estimates on the extent and severity of the earthquake were provided to California shortly after the quake struck. The results of these model intensity estimates and the actual damage assessments will be compared.

5.0 CHEMICAL SPILLS AND RELEASES

FEMA has adapted the Army's

approved chemical release model, D2PC, which provides estimates of the spread of toxic chemicals. This model is very easy to use and only requires local weather conditions (wind speed, direction, stability class) and the type and amount of chemical accidently released. The model's output is provided to the GIS. The user sees a visualization of the dangerous areas caused by the spill and, using the geographic information system and the population database, estimates the population at risk.

Examples of the utility of the model, GIS, and databases will be presented.

6.0 FIRES

FEMA pursued several efforts to provide more comprehensive real time information concerning urban and woodland fires to local, state, and federal disaster relief teams. These efforts combine the remote sensing capabilities of the meteorological sensors onboard the NOAA satellites with fire spread simulation models, and geographic information systems (GIS). With this technology the potential fire damage and population at risk can be estimated.

The first task was to develop software to determine which areas of the image represented fire. The software used a variety of techniques to classify each pixel in the image as fire, earth reflections, and normal "hot spots."

Next, software was adapted to determine the exact ground location of each pixel in the image as cited above.

When the satellite data had been successfully processed, the next step was to integrate the information into the ARC/INFO GIS. Polygons representing the extent of the fires were generated from the point data developed from the image. These polygons were intersected with population and housing and other resource information to produce estimates of fire damage. In addition, the satellite-determined fire locations serve as seed points for a simulation model that estimates the spread of the fire. Again, the estimates from the simulation model are integrated into the GIS for analysis of population, housing, facilities, and resources at risk.

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PLANETARY DATA DISTRIBUTION SYSTEM

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ABSTRACT

A system is described that distributes digitized video, text data, and alarm notifications reflecting constantly changing conditions in the planetary environment as well as high-priority information affecting large populations. Data are delivered in near-real time to users worldwide via existing transmission facilities. The system is intended to warn of conditions such as earthquakes, tsunamis, severe weather, and solar disturbances, providing substantially more information than current methods while also continuously relaying large amounts of scientific and other data. Inputs to the system originate from a network of sensors plus Government and other automated information sources. Data handling speed is significantly enhanced by a DoD-developed data/image compression scheme combining digitized video with text and adapted to the transmission media.

Information on the system is directly accessible almost anywhere in the world via desktop-type computers equipped with special low-cost data converters, decoding hardware, and associated software. Transmission is via conventional television relay satellites and distributed by cable systems, individual satellite receivers, or other bandwidth-capable networks. The system can be configured to distribute information to some users and not others and can accommodate a wide variety of data types.

INTRODUCTION

Despite rapidly broadening commercial and Government efforts to increase information flow to the public via interactive television and related systems, significantly less interest has focused on using emerging distribution technologies for wide area dissemination of emergency and other quickly changing data. Terrestrial phenomena such as earthquakes, severe weather, and tsunamis as well as events affecting the near-earth space environment such as solar flares and geomagnetic storms have significant impacts on human activities but existing warning delivery systems tend to be diverse and provide limited coverage.

The system described below uses a Department of Defense-developed data handling system in conjunction with conventional transmission facilities to deliver time-critical information virtually instantaneously to desktop-type computers in any part of the developed world. Information to be broadcast is assembled at a central location, formatted into data streams, and relayed to satellites for distribution.

The data streams are received via conventional TeleVision Receive Only (TVRO) facilities and then decoded by low-cost ($200-400/user) equipment installed in a desktop-type computer. The system runs in the background on the user's machine, allowing the host computer to perform other tasks while incoming data are automatically retrieved and stored.

Distinct from interactive systems or data bases requiring individual user access, this approach represents a continuous flow of constantly updated emergency, scientific, and educational data while simultaneously providing information useful to the general public.

The PLANETARY DATA DISTRIBUTION SYSTEM (PDDS)

The primary equipment for the current system is located at two sites (see Figure 1): A central data collection and encoding facility at the U. S. Information Agency's (USIA) Network Control Center in Washington, D. C. and a dedicated data acquisition/interface device located at the National Oceanic and Atmospheric Administration (NOAA) Space Environment Laboratory (SEL) in Boulder, Colorado. Other equipment for relaying the data products via satellite is modular and can be installed at any conventional television uplink site.

Necessary equipment to receive the data consists of a satellite dish and receiver capable of recovering the relayed television signal, a signal converter, and a special circuit board for a desktop-type computer. Individual user equipment is described in greater detail below. Significant in this application is the capability for mass distribution of the entire data product via cable TV systems, bandwidth-capable computer networks, and other existing and emerging information distribution systems.

The current system provides two data products: a high data-rate feed (512 kbits/second) intended for the U. S. (all 50 states), Canada, Mexico, and the Caribbean Region plus a slower feed (64 kbits/second) with global coverage.

The domestic 512 kbit/second product is transmitted on a subcarrier accompanying commercial television signals being relayed via conventional TV satellites. Simultaneously, the global 64 kbit/second stream is inserted in the Vertical Blanking Interval (VBI) of the video signal of the USIA WORLDNET Television service. Containing a somewhat smaller data set, the VBI-based transmission product is intended for the worldwide environmental, scientific, technical, and educational communities; it will also be receivable throughout North America.

All data are encoded and prioritized using HORACE[1], a DoD-developed data-transmission protocol, which allows mixing of video and text data. Data flow is configured such that low priority information can be interrupted to send higher priority data and then lower priority flow resumed. HORACE also embodies a video data compression scheme allowing eight-bit video pixels to be compressed to from 1.5 to 2 bits; for most storage and viewing purposes, recovered image quality exceeds the display device capabilities.

This highly flexible, real-time approach to information distribution is not limited to any particular type of data and can, in fact, be used in a wide variety of applications such as information services, advertising, and messaging.

PDDS Inputs and Transmitted Data

Input data for the system come from a worldwide network of sensors, spacecraft, observatories, and Government agencies, whose information is continuously assembled at a central facility in Washington, D. C. Of particular importance is the data from the NOAA Space Environment Laboratory (SEL). That organization tracks conditions in the near-earth space environment and serves as a worldwide warning center for disturbances having significant impacts on spacecraft operations, communications, and navigation; PDDS gives the SEL an unprecedented ability to provide virtually instantaneous global warning.

Current plans include the following products to be carried via both domestic and global feeds:

Near-real-time earthquake data from the National Earthquake Information Center.

Tsunami warnings from the NOAA Tsunami Warning Center.

Warnings of disturbances in the near-earth space environment which pose hazards to human activities (e. g., manned spacecraft, satellites, navigation systems, communications).

The latest available satellite weather imagery from GOES, METEOSAT 4, and GMS.

The latest solar images (in hydrogen-alpha and other wavelengths) from solar observatories around the world.

Continuously updated data on the sun and solar-terrestrial environment from the NOAA Space Environment Laboratory.

In addition to the above products, the domestic feed is projected to also include:

Detailed earthquake data and maps.

Severe weather warnings and graphics with affected areas depicted.

SIGMET, AIRMET, and other high-priority data from the National Weather Service and the Federal Aviation Administration.

Disaster-related data and graphics from the Federal Emergency Management Agency (FEMA).

Subcarrier-based Distribution

The domestic, subcarrier-based data streams consist of two components: a 1.544 Mbit/second (T-1 rate) product which includes an encrypted component. The combined streams are sent via leased telephone data line to a satellite uplink facility where more data may be added before being put on a subcarrier for transmission.

In the satellite's reception footprint, conventional equipment at a TVRO station (e. g., cable TV companies or individual home receiving dishes) takes the subcarrier from the television signal. One local distribution approach is for a

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[1] U. S. Patent No. 5,062,136, "Telecommunication System and Method."

cable TV company to use commercial equipment to convert the subcarrier signal to a radio frequency and make it available in the FM portion of its cable spectrum. Individual TVRO users can access the subcarrier directly from where it appears at the "wideband output" of their satellite receiver.

A special low-cost circuit board in a desktop-type computer separates the data from the distribution signal, decodes it, and makes it available for use. The circuit board contains its own microprocessor, memory, and instructions so the entire reception, decoding, and data handling operations can take place independent of the computer's main processor.

All arriving data are examined by all user machines but only selected information is accepted. Selections of data to be extracted are made during software initialization and may be changed by the user at any time.

Vertical Blanking Interval (VBI[2])-based Distribution

Using the VBI of a television signal broadcast worldwide to distribute a data/image product appears to represent a cost-effective application of that capability since the technology involved is well established and accessible throughout the world. Emphasis in this global feed is placed on environmental and scientific information and, despite the slower 64 kbit/second data rate, large amounts of information are still transferred.

Devices similar to "closed-caption" encoders pack outgoing data into the VBI of both NTSC and PAL video waveforms which are then uplinked to various satellites for relay throughout the world. Users in the satellites' footprints employ low-cost VBI-based decoders to extract the data and make it available to desktop-type computers. Though data-recovery hardware differs from the subcarrier-based scheme, data handling and software is essentially the same.

An important capability of the global feed is not only providing essentially instantaneous worldwide warning of hazardous events in the solar-terrestrial environment (current warning times range into the tens of minutes--unacceptably long for many emerging high-tech systems), but also serving as a high-speed conduit for important scientific data which would normally take from weeks to months to distribute. The PDDS worldwide service also provides continuously updated weather satellite imagery, solar data, and communications advisories.

Data Format

Because the system continuously broadcasts over a wide area and users anywhere can begin monitoring the system at any time, the delivery method is totally asynchronous and capable of transmitting an entire data package relatively quickly.

To accomplish this, the overall scheme employs a repeating data "frame" containing the most current information and digitized video images. Inside the frame, each piece of data has its own unique and unchanging numerical identity, called a "tag," with a maximum of 65,536 tags possible in this particular application. Once identified by its unique number, user software immediately begins organizing incoming tags according to user-set preferences. Information inside each tag can change at any time with software designed to detect the new data and update accordingly.

The number of tags and the number of data bytes in each tag can vary (e. g., the tag with the current "solar flux" value contains just a few bytes while the tag containing the latest GOES satellite image has many more) with software controlling the process. The design objective was to achieve an approach that allows a user to obtain all current information within a short time after beginning to receive data.

Information is transferred sequentially from the host computer with higher priority data interrupting and replacing the flow of lower priority data. After the higher priority information is sent, the lower priority stream resumes; all data tags are uniquely specified in the stream so user equipment will handle them accordingly.

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[2] In a television set, this is the time the electron gun is turned off while its beam is repositioned back to the top left corner of the screen. This interval is equivalent to the time necessary to sweep out 21 horizontal picture lines and can be seen as a black bar between frames if a television's "vertical hold" control is adjusted to allow the picture to roll. Line 21 is used in the United States to insert "closed captions" for hearing-impaired viewers; PDDS uses lines 10 through 18.

In the current system configuration, there are four levels of data prioritization with others possible:

1. ASCII character-based alarm data.
2. ASCII character-based text that changes rapidly.
3. Digitized image and/or line-drawing files.
4. ASCII character-based text that changes slowly.

Secure Data Capabilities

Encryption technology allows wide flexibility in offering secure data services as part of the domestic product while providing a method to recover system operating costs via subscription fees. A portion of the data frame as well as separate segments of the data stream have been reserved for this purpose.

In addition to each user's unique "address," any number of different tags can possess different encryption/decryption keys such that only authorized user(s) can receive and access their assigned data. Further, these services are based on state-of-the-art techniques allowing continuous changes to encryption keys and secure tag assignments, ensuring a high degree of data security. All text and image transfer capabilities in the unsecured data product are also available in the secure service.

Circuit Board and Software

Recovered data are presented to a circuit board installed in the individual user's desktop computer. The data stream is decoded by software and information routed to destinations determined by the user. Under software control, data can be displayed, stored in files, or both. Boards will possess sufficient RAM capacity to store incoming data such that incoming new information is not displayed until completely received. Unless incoming data in a given tag have been designated for storage in files, new data replace the old as they arrive.

Via software, data priorities originally assigned by the system can be manually overridden and displays selected or deselected at the user's option. Software design allows for archived data files to be compatible with and accessible by data base applications. Depending on the host computer's operating system and machine architecture, the entire PDDS application is also designed to allow itself to run in the "background" so the computer can be used for other purposes simultaneously.

Other software options include the capability to store specified image files and retrieve them sequentially, thus producing "movies" (e. g., automatically storing a series of GOES weather images as they arrive and later playing them back to observe air mass movement patterns). Another option is to enable the computer to enter the PDDS program automatically after a set interval, go to a predetermined data page, and display it; in this application, the latest GOES full-disk earth image could be displayed as a "screen saver."

Initial circuit board design requirements call for compatibility with IBM PC-type desktop computers but additional configurations including a totally external unit for laptops and a Macintosh-based circuit board are planned.

For an individual user, unit cost, including Signal Converter, Circuit Board, Software, and Software Documentation is projected to be approximately US$200-400 which is expected to drop substantially as manufacturing volume increases. Moreover, hardware versions are planned that allow the Signal Converter to reside on the circuit board itself, depending upon the method of distributing data (e. g., subcarriers, RF signals via cable TV, Local Area Networks, etc.).

FUTURE EXPANSION

An important priority in developing PDDS is making the data stream available to the many emerging information services that offer large numbers of television channels. Not only is the present configuration immediately marketable, but additional products are possible which contain specialized data and images. Also ongoing is an effort to include PDDS as part of the National Information Infrastructure (NII) being developed by the U. S. Government.

Both hardware and software capabilities are expected to further expand and develop after the system becomes operational. Specialized software intended to handle certain categories of data is easily designed (e. g., extracting user-specified tags, archiving, processing, analyzing, and displaying the data) as is specific hardware (outside-world interfaces that act on incoming data).

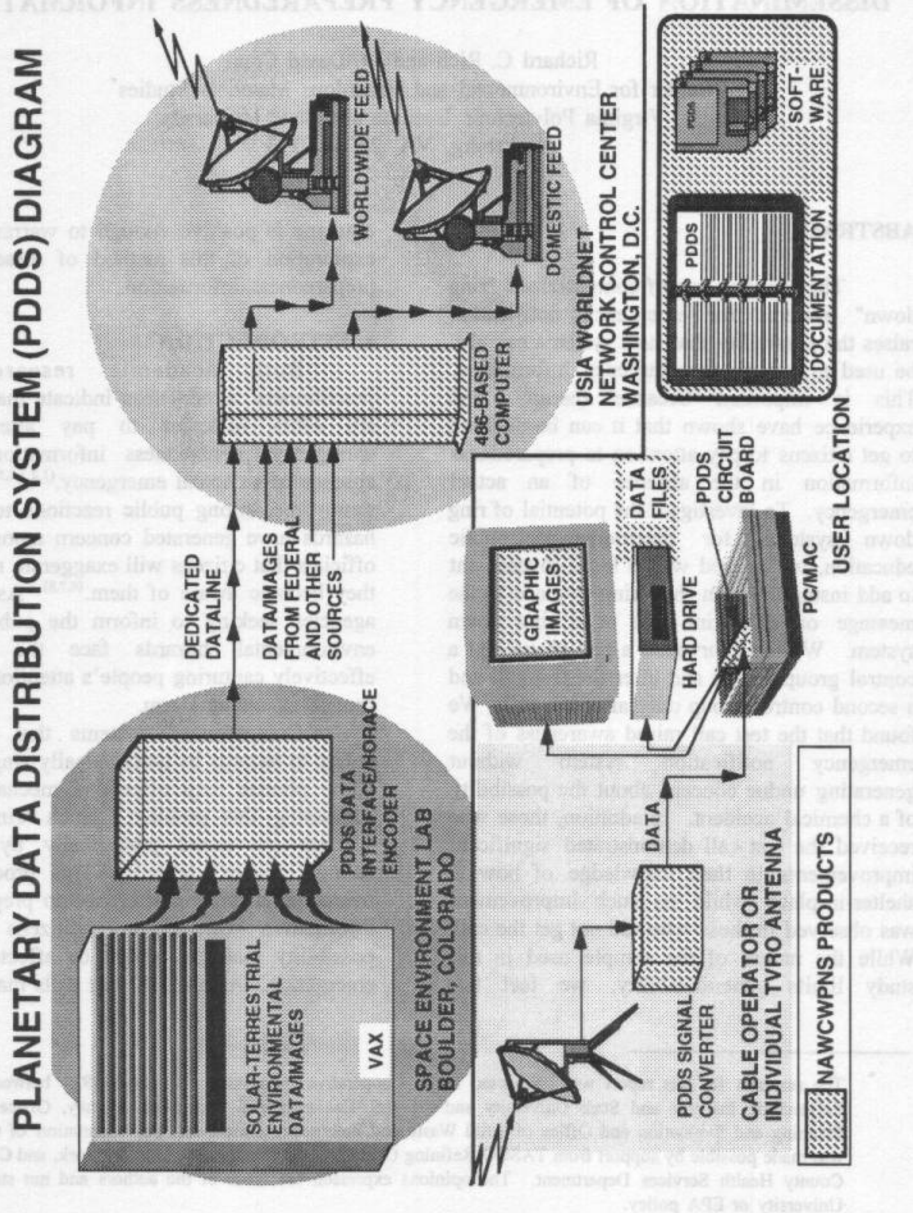
A notable future enhancement to the PDDS will be serving as a primary real-time worldwide relay for data from the Advanced Composition Explorer (ACE) satellite. This spacecraft will orbit a point of gravitational equilibrium near the sun, monitoring solar magnetic fields and particle emissions. As part of the PDDS product, ACE will provide an approximately 30-minute advance warning of high-energy sub-atomic particles and other solar outbursts that have significant impacts on earth-orbiting satellite systems and other terrestrial activities.

CONCLUSION

The potential user community for a system such as PDDS appears substantial. Because the system uses existing resources and reception equipment available at low cost, it appears to represent an excellent opportunity to establish a domestic and international real-time information network. Moreover, a primary design objective of PDDS was to produce a data product inherently distributable via mass broadcast media; this seems to make it marketable not only as a stand-alone system, but also as a potential offering for the quickly emerging family of information delivery systems.

At this writing, several U. S. Government agencies are actively involved in evaluating the capabilities PDDS would provide while several more have already expressed interest in participating. The NOAA Space Environment Laboratory intends to use PDDS as a primary data distribution network while officials in all branches of the U. S. military have plans for the system's capabilities. Also an enthusiastic participant is the solar research community and their worldwide system of observatories, with several major research laboratories currently gathering input from their scientists on ways to use the data PDDS would provide.

But seemingly the most important users would be the world's schools, colleges, and universities as well as the public at large as more and more data becomes available via systems like PDDS. Putting a global and instantaneous source of data literally at the fingertips of anyone with a home computer appears a natural direction for information technology.



PLANETARY DATA DISTRIBUTION SYSTEM (PDDS) DIAGRAM
SOLAR-TERRESTRIAL ENVIRONMENTAL DATA/IMAGES
VAX
SPACE ENVIRONMENT LAB BOULDER, COLORADO
PDDS DATA INTERFACE/HORACE ENCODER
DEDICATED DATALINE
DATA/IMAGES FROM FEDERAL AND OTHER SOURCES
486-BASED COMPUTER
WORLDWIDE FEED
DOMESTIC FEED
USIA WORLDNET NETWORK CONTROL CENTER WASHINGTON, D.C.
PDDS DOCUMENTATION
SOFT-WARE
PDDS SIGNAL CONVERTER
DATA
GRAPHIC IMAGES
HARD DRIVE
DATA FILES
PDDS CIRCUIT BOARD
PC/MAC
CABLE OPERATOR OR INDIVIDUAL TVRO ANTENNA
USER LOCATION
NAWCWPNS PRODUCTS

AUTOMATED EMERGENCY NOTIFICATION SYSTEMS AND THE DISSEMINATION OF EMERGENCY PREPAREDNESS INFORMATION

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ABSTRACT

The growing use of computerized "ring down" systems for emergency notification raises the possibility that such systems can also be used to convey preemergency information. This is important because research and experience have shown that it can be difficult to get citizens to pay attention to preparedness information in the absence of an actual emergency. To investigate the potential of ring down systems for preemergency public education, we worked with a local government to add instructions on sheltering-in-place to the message on a routine test of a ring down system. We then surveyed a test group and a control group before and after the test call and a second control group only after the call. We found that the test call raised awareness of the emergency notification system without generating undue concern about the possibility of a chemical accident. In addition, those who received the test call demonstrated significant improvements in their knowledge of how to shelter-in-place while no such improvement was observed in those who did not get the call. While the nature of the sample used in this study limits generalizability, we feel this outcome is positive enough to warrant further exploration of this method of disseminating preparedness information.

1. INTRODUCTION

Both academic research and practitioners' experiences indicate that citizens are often reluctant to pay attention to emergency preparedness information in the absence of an actual emergency.[1,2,3,4,5] At the same time, strong public reactions to specific hazards have generated concern among public officials that citizens will exaggerate risks once they become aware of them.[6,7,8] As a result, agencies seeking to inform the public about environmental hazards face the task of effectively capturing people's attention without provoking undue alarm.

Computerized systems that alert the public to hazards by automatically ringing their home phones may offer one mechanism for addressing this problem. Such "ring down" systems are tested periodically by actually calling citizens' homes. This process may overcome natural indifference to preparedness information by alerting citizens to the possibility that they might be affected by an emergency. As a result, test calls may present

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an excellent opportunity to effectively convey preparedness information which is often ignored when distributed in other forms (public service announcements, brochures, etc.).[9]

We sought to evaluate the potential of ring down tests as vehicles for communicating pre-emergency information by working with the Health Services Department in Contra Costa County CA to add information on how to shelter-in-place to the standard message used in a routine test of the County's ring down system known as the Community Alert Network or C.A.N. (The text of this message appears in the appendix to this paper.) We mailed questionnaires to randomly selected residents before and after the test call in order to evaluate its impact.

Our objectives were to learn (1) how the test call was handled when it reached citizens' homes, (2) how receiving it affected citizens' awareness of and attitudes toward chemical hazards and emergency preparedness, and (3) if the shelter-in-place message that accompanied the test call improved citizens' understanding of this self-protective technique. This article describes the methods used in the study, summarizes the findings, and assesses the implications of these results for emergency management.

2. RESEARCH METHODS

Contra Costa County government provided us with address labels corresponding to all the telephones numbers C.A.N. had for the areas scheduled to receive the test call and for selected streets adjoining the test areas. Since C.A.N. was legally prohibited from identifying citizens, the labels had neither residents' names nor apartment numbers on them. This forced us to use an impersonal mailing which probably reduced the response rate. It also meant that we could not be sure of mail delivery to apartments. Accordingly, we removed all multiple labels at the same address in an effort to eliminate apartments from the sample. This restricted our sample to single-family residences with listed (or voluntarily reported) telephone numbers.

We must also note that while these areas were primarily residential, any businesses in the C.A.N. data base for the area were also included in the set of labels provided by the county. Since they could not be identified as businesses from the labels, they were unavoidably included in the mailing. As a result, we do not know the exact number of valid potential respondents and can not report response rates or calculate sampling errors with complete accuracy. In what follows, we make the conservative assumption that all the addresses to which we mailed questionnaires were residences. To the extent that some of the addresses were commercial (and had no valid respondents), this assumption has the effect of <u>under</u>stating the response rates and <u>over</u>stating the sampling errors.

We then drew a systematic random sample of each of three groups from the address labels. They were:

The Test Group consisted of people who were scheduled to receive a phone call as part of the C.A.N. test. This group was sent a questionnaire both before and after the test call. Of the 668 addresses in this group, 209 responded to the pretest mailing (for a 31% pretest response rate). Of this 209, 130 responded to the posttest mailing (for a posttest response rate of 62%).

Control Group 1 was drawn from a list of addresses on streets that were adjacent to those scheduled to receive the test call but that were <u>not</u> to receive the call. This group was sent a questionnaire both before and after the date of the test call. Inclusion of this group allows us to isolate the effect of the test call from other factors that might have changed citizens' responses (like news reports of a chemical accident). Of the 181 addresses in this group, 74 responded to the first mailing (for a 41% pretest response rate). Thirty nine of the 74 responded to the second mailing (to give a posttest response rate of 53%).

Control Group 2 was drawn from addresses that were in the areas scheduled to receive the C.A.N. test call but had not been selected for the test group and to which we did **not** send a pretest questionnaire. This group received only a post test mailing and was included in the study to allow us to gauge any "test effect" created by sending the first questionnaire. Seventy four of the 222 addresses in this group returned the posttest questionnaire (for a response rate of 33%).

There were no statistically significant differences between the test group and either control group in gender or educational level, and the test group and control group 1 did not differ statistically in age. However, the test group was slightly younger than control group 2. Since age was not a strong predictor of responses to any of the questions on which we compared the test group and control group 2, we do not feel that this small demographic difference makes control group 2 an inappropriate comparison group for purposes of identifying any test effect.

Several features of the sample used in this study must be recognized. First, the sample included **only** residents of single-family dwellings and excluded most renters. This means that respondents are likely to be a little older, more affluent, and more educated than a cross section of the public would be. As a result, responses from this sample are likely to overstate the level of citizens' information about chemical hazards and emergency preparedness. Second, while the sample is large enough to represent residents of single-family dwellings in or near the test calling areas, it is small in absolute size and restricted to a single county. Accordingly, we must be cautious about generalizing to other populations from the results of this study.

3. RESULTS

Initial responses from the test group and control group 1 revealed that respondents had very little awareness of emergency procedures. Only 18% said they had seen or heard a description of the emergency notification system, and only 9% claim to have seen instructions on evacuation procedures. When asked if they would know what to do if asked to evacuate, only 28% said they would know what to take with them, 18% said they would know what routes to use, and 9% said they would know where to go for shelter.

Only 13% reported having seen or heard instructions on how to shelter-in-place. When asked in an open-ended format what steps to take to shelter in a chemical emergency, only a minority of respondents were able to identify appropriate actions. In addition, 61% (including many who had guessed at appropriate actions) volunteered that they did not know what steps to take.

3.1 Handling of the Test Call

To be effective as an educational tool, a test call must reach its intended audience. We examined the responses of the 130 members of the test group who returned the posttest questionnaire to determine how effective the test call had been in this regard. Only 42% (55 individuals) reported having received the call. This relatively low contact rate is probably explained by the fact that the test call involved only one attempt to reach each phone number. In an actual emergency, multiple attempts would be made and the contact rate is likely to be much higher.

Of those respondents who reported receiving the C.A.N. call, 70% said that they personally took the call. Twenty two percent reported that the call went to an answering machine. Forty eight percent of these said that the machine got the full message, 38% said it got only part of the message, and 14% did not know how much of the message was captured.

An impressive 86% of those who received the call said they listened to the entire message, 4% listened to only part of it, and 7% reported hanging up as soon as they heard that it was a C.A.N. test call. The rest indicated that they did not know how much of the message was received or gave some other response.

At the end of the test call citizens had the option of pressing a button to receive additional information on how to shelter-in-place. Twenty two percent said that they took advantage of this option. In an effort to determine how much impact the test call had, we asked if respondents discussed the call with others in their household. Forty seven percent indicated that they did discuss the test call after it came. Of these, 33% said they talked about sheltering-in-place, 3% discussed the emergency notification system, 3% discussed chemical hazards, and 58% gave an answer that was too general to classify, like "how important it was."

Aside from the low contact rate caused by the single attempt at each number, these data indicate that the test call was fairly successful in reaching its intended audience. Answering machines did not prove to be a major problem and most people listened to the full message.

3.2 Impact of the Test Call

This study was designed primarily to ask (1) what difference the test call made in citizens' perceptions of hazards and emergency notification procedures, and (2) if the preparedness message that accompanied the test call increased citizens' information about what to do in an emergency. To address the first question, compared the pretest and posttest responses of the 55 members of the test group who reported receiving the C.A.N. call with the responses of the 39 members of control group 1 who responded to both mailings.

First, it is worth noting that, when asked how they expected to be notified in the event of an emergency, 71% of those <u>who got the call</u> identified the C.A.N. while only 11% of those who did <u>not</u> get the call mentioned the C.A.N. Since less than 10% of both the test and control groups expected to be notified by the C.A.N. in the pretest, it seems safe to assume that the test call alerted people to the existence and purpose of the notification system.

Second, in light of the common view that efforts to educate the public about chemical hazards might create undue concern, we wanted to know if the test call increased citizens' estimates of the possibility of a chemical accident. In both the pretest and posttest questionnaire we asked residents what they thought the chances were that their neighborhood might be affected by a chemical emergency "within the next year or so". The results are reported in Table I.

Table I
Perceived Chance of a Chemical Accident

Response	Test Group (N=55*) pretest	Test Group (N=55*) posttest	Control Group1 (N=39+) pretest	Control Group1 (N=39+) posttest
NO CHANCE	20%	13%	26%	23%
LITTLE CHANCE	50%	52%	28%	36%
SUBSTANTIAL CHANCE	30%	33%	43%	41%
DON'T KNOW	0%	2%	3%	0%

*Includes only those who returned both the first and second questionnaires and received the test call.
+Includes only those who returned both the first and second questionnaires but did not receive the test call.

While members of the control group were more likely to feel that there was "a substantial chance" of a chemical accident in the pretest, there was no statistically significant overall increase or decrease in their estimates from pretest to posttest. Similarly, while those who got the test call were less likely to say that there was "no chance" after the call than before, there was no dramatic increase in their overall likelihood estimate from pretest to posttest. While 64% of those receiving the call who had said "no chance" in the pretest switched to the objectively more realistic "very little chance" response in the posttest, none of them switched to the "substantial chance" category. Only 12% of the test group members who had said "very little chance" in the pretest switched to "a substantial chance" in the posttest.

Our use of a single-item indicator of the concept of "perceived risk" calls for caution in drawing conclusions from this study. However, these results indicate that the test call successfully alerted some who received it to the possibility of a chemical emergency without causing any undue alarm.

To judge the success with which ring down tests can be used to educate the public we must ask if citizens learned anything about sheltering-in-place from the call. To answer that question, we compared the pretest and posttest responses of the 55 citizens who both got the C.A.N. call and returned the second questionnaire, and then contrasted those responses with the reactions of the two control groups.

As background, it is important to note that while only 20% of the 55 citizens who got the test call said they had seen or heard instructions on how to shelter-in-place prior to the call, after the call, 64% said that they had seen or heard such instructions. Seventy seven percent of those who said they had received such instructions cited the C.A.N. test call as the source. By comparison, in the posttest only 10% of control group 1 who did not get the test call indicated that they had seen or heard instructions on how to shelter.

Table II compares those who got the call with those who did not get the call with respect to their knowledge of what steps to take to shelter-in-place. For those who received the call, there were statistically significant improvements in the percent of respondents who named every step in effective sheltering. For those who did not receive the call, there was a significant improvement in only one category -- "go or stay indoors". Our prior experience with questions on sheltering suggests that this one difference may be a matter of chance since some respondents assume that people will go indoors and do not bother to mention it.[10] In addition, there was a dramatic reduction in the proportion of the test group who said that they did not know what to do to shelter (from 46% to 20%) but no statistically significant change in the proportion of control group 1 who indicated that they did not know what to do.

Table II

Respondents' Knowledge of Sheltering-in-Place

	Test Group (N=55)		Control Group1 (N=39)	
Step Named	Pretest	Posttest	Pretest	Posttest
Go/stay indoors	27%	65%	18%	33%
Close doors/windows	47%	85%	46%	46%
Seal doors/windows	9%	50%	13%	18%
Shut off ventilation	22%	40%	5%	5%
Listen to TV/radio	18%	29%	3%	10%
Close Fireplace	6%	27%	8%	5%
Don't use phone	0%	4%	0%	0%
Don't know what to do	46%	20%	54%	49%

Did this improvement in knowledge of sheltering procedures result from the test call or did our first questionnaire cause people to learn about sheltering in some other way? To answer this question we compared the test group to control group 2 whose members got the test call, but did **not** get a pretest mailing. Table III shows the results. In the posttest members of control group 2 exhibited a knowledge of sheltering that was statistically indistinguishable from that of the test group. This indicates that there was no "test effect." This conclusion is consistent with the fact that the overwhelming majority of respondents in both groups who said they had been exposed to information on how to shelter cited the test call as the source of that information.

Table III
Posttest Knowledge of Sheltering Procedures

Step Named	Test Group (N = 55)	Control Group2 (N = 38)
Go/Stay Indoors	65%	62%
Close doors/windows	85%	74%
Seal doors/Windows	50%	53%
Shut off ventilation	40%	41%
Listen to TV/radio	29%	29%
Close fireplace	27%	35%
Don't use phone	4%	3%
Don't know what to do	20%	20%

4. CONCLUSIONS

Overall, our findings suggest that the test call served to educate those who received and listened to it about both emergency notification and shelter-in-place procedures. While recognizing the limitations imposed by the nature of this sample, we would argue that the outcome is positive enough to warrant further exploration of this method of disseminating preparedness information. Future research on this topic should address the following issues. (1) Finding ways to ensure that the contact rate on test calls is high enough to inform most citizens. This will involve both efforts to obtain unlisted numbers for the notification system and making multiple attempts to reach each number even in the test calls. (2) Verifying the results of this study with a larger and more diverse sample than was available for this study. (3) Testing to see how long the information is retained by reinterviewing citizens after the posttest. (4) Assessing the impact of test calls on risk perceptions more thoroughly than our single-item measure of risk perception allowed. (5) Evaluating the effectiveness of this technique with other message content like evacuation procedures. If future research confirms our findings, communities with ring-down systems may want to experiment with using routine tests calls to disseminate emergency preparedness instructions to their citizens.

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APPENDIX
TEXT OF THE TEST CALL MESSAGE

THIS IS A TEST OF CONTRA COSTA COUNTY'S COMMUNITY ALERT NETWORK. AGAIN, THIS IS ONLY A TEST. IF THIS HAD BEEN A REAL EMERGENCY INVOLVING HAZARDOUS CHEMICALS, YOU MIGHT HAVE BEEN ASKED TO "SHELTER-IN-PLACE". IT IS USUALLY SAFER TO REMAIN INSIDE A BUILDING WHILE A CLOUD OF CHEMICALS PASSES OVERHEAD, INSTEAD OF TRYING TO EVACUATE IMMEDIATELY. IF THIS WERE AN ACTUAL EMERGENCY AND YOU WERE ASKED TO SHELTER-IN-PLACE YOU SHOULD STAY INSIDE, LOCK ALL DOORS AND WINDOWS, TURN OFF HEATING AND COOLING SYSTEMS, PUT OUT FIREPLACE FIRES AND CLOSE THE FIREPLACE DAMPERS. ANY OPENINGS AROUND DOORS, WINDOWS, AND VENTS SHOULD BE SEALED WITH TAPE OR ANY AVAILABLE MATERIALS. STAY OFF YOUR PHONE UNLESS YOU HAVE A LIFE THREATENING EMERGENCY. IN A REAL EMERGENCY YOU SHOULD TUNE YOUR RADIO TO KISS AM990 OR FM92 FOR FURTHER INFORMATION AND INSTRUCTIONS. AGAIN THIS HAS BEEN A TEST. IF YOU WOULD LIKE MORE INFORMATION ON SHELTER-IN-PLACE LISTEN CAREFULLY TO THE FOLLOWING INSTRUCTIONS. IF YOU WOULD LIKE MORE INFORMATION, PLEASE PRESS THE NUMBER 5 ON YOUR TOUCH TONE PHONE NOW. IF YOU HAVE A ROTARY PHONE PLEASE CALL 646-2286 DURING NORMAL BUSINESS HOURS AND REQUEST THIS INFORMATION. AGAIN THAT NUMBER IS 646-2286. THANK YOU.

RESPONSE TO THOSE REQUESTING MORE INFORMATION: YOU HAVE INDICATED THAT YOU WOULD LIKE MORE INFORMATION ON SHELTER-IN-PLACE. PLEASE ALLOW THREE WEEKS FOR DELIVERY. IF YOU DO NOT RECEIVE THE INFORMATION, PLEASE CALL 646-2286. AGAIN THAT NUMBER IS 646-2286. THANK YOU!

RECENT RESEARCH IN EMERGENCY MANAGEMENT

SIMULATED IMAGES FOR EMERGENCY MANAGEMENT TRAINING

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ABSTRACT

The use of simulated images for training, planning, and communications in the emergency management community can yield significant benefits. Aerial photographs of emergency or disaster situations and scenarios that are not available prior to actual crisis situations can be depicted using simulated images and used to provide more realistic training. Images of dynamic emergency situations can be used to train personnel to plan in response to the features depicted in the images. Specifically, the integration of synthetic imagery created by SIGS (Synthetic Image Generation System) is discussed. SIGS can generate synthetic aerial photographs that approach photo-realism using inputs of aerial photographs, digital elevation data, and 3D models of cultural features (buildings, bridges) and mobile objects (trucks, aircraft, ships, etc.). The 3D models can be represented as operational, damaged, or destroyed and other cues such as vehicle tracks and ship wakes can be depicted. The SIGS operator can edit the contents of a scene interactively to depict a range of disaster scenes. The operator can also select from a variety of geographic locations depicted in the background scenes and the scene can be easily and quickly modified to represent changes over time, including the simulation of various weather conditions such as fog, smoke, and haze and the selection of daylight conditions such as sun angle and viewing location.

A training scenario is presented covering several aspects of recovery response, rescue, and from a simulated air crash into Boston Harbor. Sample synthetic images depicting the disaster scene are presented where specific aspects of mitigation and recovery can be emphasized by tailoring the synthetic image to depict unusual conditions. Implementation challenges include effectively scripting scenario alternatives to make use of synthetic imagery, quickly generating new imagery and finding ways to make this technology useful at all levels of incident management.

There is a Need for More Realism in Desktop Emergency Management Training

Everyone recognizes that full-scale emergency management exercises that involve personnel, equipment, and facilities are very expensive and must be closely scripted to accomplish specific objectives. In fact, most are used to demonstrate an existing capability or reveal deficiencies in standing procedures. There is usually little room for creativity and innovation. Consequently, full-scale exercises are supplemented by desktop paper exercises that involve a limited set of personnel (usually top decision-makers or department heads) and little in the way of equipment or facilities.

Desktop exercises can be supplemented with detailed computerized maps and database information as described by Morentz, et al. [1], to give some capability to "visualize" what is going on in an evolving emergency training scenario. However, a continuing drawback to desktop exercises is their lack of realism. Participants are always aware that they are not participating in the high-pressure, time-critical, ambiguous, information-sparse, imperfect environment of an actual emergency incident. As such, they miss out on the valuable learning experiences that can result from actively participating in a dynamic exercise that requires creative decision-making and innovative solutions to problems. Effective emergency management represents the culmination of years of training and experience and hinges on a manager's ability to quickly assess the emergency, develop a plan of action and then change that plan of action as myriad possible complications arise. How do you train emergency managers to develop this "gut feel" for the emergency situation? How can you expose them to the hundreds (or maybe thousands) of possible variations in a scenario that they might otherwise never see or experience in their entire careers? How can you do this with minimal expense and preparation?

A Synthetic Imagery Solution Addresses the Issues of Increased Realism

A key factor in creating added realism in a desktop emergency management exercise would be the availability of an "eye-in-the-sky" photograph of the emergency area. For a localized area such as a vehicle accident or an explosion this would be similar to having a camera in a helicopter overlooking the scene. More wide-ranging emergencies such as hurricane damage, forest fires, or chemical spills might involve both real-time aerial as well as satellite photographs of the event and surrounding area. While these sources will be available to emergency managers in real time someday (and some are available today to a limited extent), their simulation gives the exercise participants a better "feel" for being on, or at least over, the emergency scene.

Simulated images of emergency scenes need to be backed up with actual data that faithfully represents the terrain and other unchanging frames of reference. It is the damage and the dynamic objects in the scene that are manipulated to create realism. An example of this is the scenery for the extensive fires in Yellowstone National Park in 1988. TASC created imagery of the area from satellite photographs and then "flew" the observer through and around the area to establish the orientation of the fires. While fire fighting managers were already oriented on map grids, the response to the synthetic terrain fly-by was that it captured the realism of being there. Similar fly-by scenarios were prepared of facilities in the Middle East and of Sarajevo for ABC News. ABC Sports used a similar TASC rendition of downtown Calgary and the surrounding mountains as its lead-in for coverage of the 1988 Winter Olympics. Similar synthetic imagery of terrain fly-bys has been developed for Nova and National Geographic specials. The objective in each case was to give the viewers a general perspective of the terrain and a visual appreciation for the key features in the areas of interest.

Finally, if synthetic images are to add realism to emergency management training, instructors need to be familiar with the image creation and manipulation tools so they can set the pace of the training and draw out creative solutions in response to changing situations. One of the challenges summarized below is for synthetic imagery to be used where it will have the most impact on emergency training. Whether this is at the national decision-maker level, where participants are remotely distanced from the emergency and may need a greater appreciation for its scope, or if it is at the departmental or command level closer to the action remains to be seen.

An Operational Command System With Simulation and Training Capabilities Built in

This paper focuses on the use of synthetic imagery in emergency management training. However, we firmly believe that simulated or synthetic training should be viewed as only one part of an overall emergency management system. Figure 1 depicts the complete range of subsystems and technologies that make up this integrated system. *The training portion of the system should be embedded in the operational incident management system itself.* Training should not be an add-on but an integral part of the system that will be used in an actual emergency.

Three components of the overall architecture are worth noting. One is the *field imagery collection station*, the second is the *tactical (mobile) command unit*, and the third is the *strategic (fixed) command center*. All of these components have been integrated so that they can share images among themselves. The field imagery collection unit (SPORTS — Second-generation Portable Remote Telecommunications System) is capable of capturing high-resolution, still color images and sending them to the mobile or fixed command centers. (A video version will be available in mid-1994.) The SPORTS system can receive imagery from other sources as well as synthetic training imagery. The mobile command unit is designed for rapid deployment and serves as both a fusion point for collecting imagery from many fielded SPORTS systems and as a relay point up to the fixed command center. It can also send and receive real and synthetic imagery. Its high mobility and use of modern object-oriented graphics interfaces makes it easy to use in the high-stress field environment while tracking many activities simultaneously. (This was demonstrated during a deployment of the prototype as a command center at the 1992 Olympic Games in Barcelona, Spain.) Finally, the strategic crisis center is designed to operate on a continuous basis tracking worldwide incidents and summarizing them for federal-level decision-makers.

The Synthetic Image Generation System

SIGS, the Synthetic Image Generation System, is a software package (developed by TASC) that enables users to *very easily* and *very quickly* create near-photo-realistic synthetic imagery. The software was originally developed to support the needs of military training by providing the capability to create simulated aerial photographs that can meet the objectives of numerous training scenarios.

SIGS had to fulfill many requirements, the following being of most importance:

- SIGS had to be easy to use. This was important both because of the quantity of images that would need to be created and because of the variety of skill sets that the personnel operating SIGS would possess.

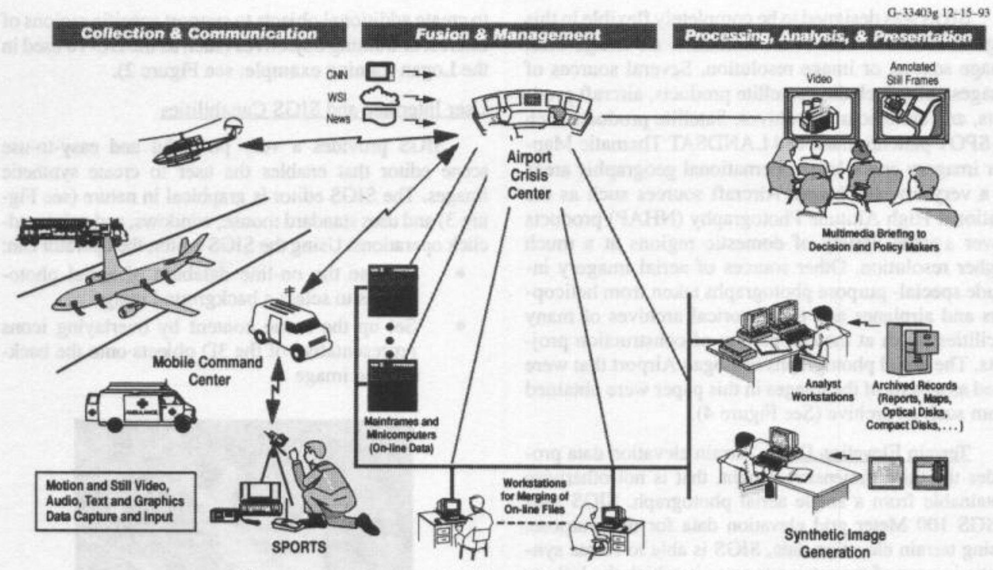

Figure 1 Integrated Incident Management Architecture

- The synthetic images created by SIGS had to be realistic enough so that they would be a *viable* training product and not be readily dismissed.
- SIGS had to be flexible and be able to create many different types of images, at various resolutions and with varying content.

The Synthetic Image Generation System succeeded in achieving these goals and more, and has been in active use in the military training arena for two years.

The flexibility of the system permits many natural extensions for the use of this capability to be explored, among them, the use of simulated, or synthetic images for Emergency Management Training. The following sections describe SIGS; the hardware and software necessary to run the software, database requirements and issues, the user interface and SIGS capabilities, and lastly, flexibility features that make SIGS usable in many training arenas. Additional technical information on SIGS can be found in a paper delivered at the 1991 International Simulation Technology Conference [2].

SIGS Architecture

SIGS is a software package that was designed to run on UNIX workstations with advanced graphics capabilities. It is written in the C programming language and uses two COTS (Commercial Off-The-Shelf) standard tool kits:

- X11 with OSF/Motif for the user interface
- GL for the image generation.

SIGS runs on most Silicon Graphics (SGI) and Sun workstations and is often accompanied by a printer and a scanner. The benefit of a printer is the ability to distribute hard copies of the simulated images to training participants. Adding a scanner to the SIGS hardware suite provides the capability to scan in aerial photographs of new areas of interest as they arise.

Databases

SIGS derives much of its flexibility to be suitable for a wide range of training arenas from the ability to vary the contents of three key databases:

- Aerial photographs
- Terrain elevation data
- Cultural and mobile objects.

Aerial Photographs. Aerial photographs are the backdrops on which each synthetic image is created. For each area of interest for which synthetic images are desired, a digital aerial photograph must be present in the SIGS database.

SIGS was designed to be completely flexible in this regard. There is almost no limitation on image size, image source, or image resolution. Several sources of images exist, including satellite products, aircraft products, and architectural archives. Satellite products such as SPOT panchromatic and LANDSAT Thematic Mapper imagery cover large international geographic areas at a very low resolution. Aircraft sources such as the National High Altitude Photography (NHAP) products cover a wide variety of domestic regions at a much higher resolution. Other sources of aerial imagery include special- purpose photographs taken from helicopters and airplanes and the historical archives of many facilities taken at the completion of construction projects. The aerial photographs of Logan Airport that were used as a basis of the images in this paper were obtained from such an archive (See Figure 4).

Terrain Elevation Data. Terrain elevation data provides the third dimension, height, that is not otherwise obtainable from a single aerial photograph. SIGS uses USGS 100 Meter grid elevation data for this purpose. Using terrain elevation data, SIGS is able to create synthetic images of mountainous areas in which the hills or mountains visually obscure buildings or vehicles that may be in the area. However, synthetic images can be created without the use of this data. The more hilly the area, the more important this data becomes. This technique would be most useful in simulating the deployment of firefighting resources against wide-area fires in rugged terrain.

Cultural and Mobile Objects. SIGS currently has a database of over 150 cultural and mobile objects that can be used to construct a synthetic image. Each object is a full three-dimensional model that was created using Alias, a commercially available model packaging. Use of a 3D model is critical because SIGS allows synthetic images to be created at any viewing angle (0 to 360 degrees azimuth) and any viewing elevation (directly overhead to 10 degrees off the horizon). The 3D model geometry is also used to cast realistic shadows from the objects onto the terrain (aerial photograph).

The SIGS database contains cultural objects such as office complexes, warehouses, and aircraft hangars. Other fixed structures such as piers, bridges, dams, fuel storage tanks, power lines, and communication towers are also present. Mobile objects in the database include several types of large and small aircraft, trucks, and ships. Although the quantity and variety of objects in this database are large enough to support many different types of military training scenarios, it is often necessary to create additional objects to support specific regions of interest or training objectives (such as the DC-10 used in the Logan training example; see Figure 2).

User Interface and SIGS Capabilities

SIGS provides a very powerful and easy-to-use scene editor that enables the user to create synthetic images. The SIGS editor is graphical in nature (see Figure 3) and uses standard mouse, windows, and point-and-click operations. Using the SIGS editor, the operator can:

- Browse the on-line database of aerial photographs to select a background image
- Set up the scene content by overlaying icons representative of the 3D objects onto the background image

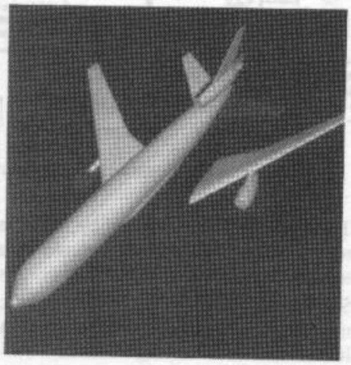

Figure 2 DC-10 Model

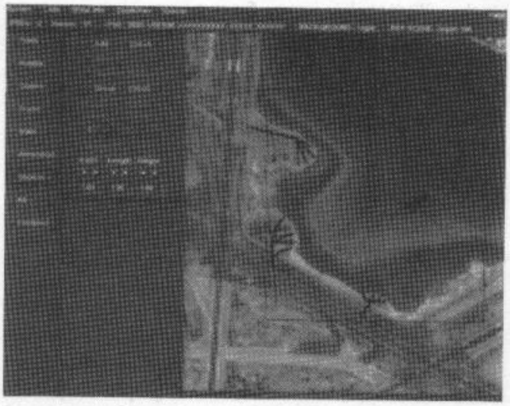

Figure 3 SIGS Interface

- Add movement cues such as vehicle tracks and ship wake
- Select the appropriate weather and atmospherics such as fog, haze, or smoke which limit scene visibility
- Add different types of trees to the base digital aerial photograph
- Set the desired output image size, image resolution, camera angle and time of day.

SIGS contains an image browsing tool that allows the user to call up an aerial photograph by its name or to browse through a catalog of image snapshots to visually select the photograph of interest. Once a photograph is selected, the user can perform scene editing.

Scene editing consists of positioning the object icons on the image, adding movement cues, adding any required damage, setting image output parameters, and then initiating the creation of the synthetic image.

If an image was being created to depict a crash at an airfield, the user would want to add several objects onto the aerial photograph. These would most likely include the crashed aircraft and numerous emergency vehicles such as fire engines and ambulances. The user positions each desired object in the image by first selecting it from a menu and then selecting the corresponding position on the aerial photograph. Each model can be resized in length, width, and height, and can be depicted as operational, damaged, or destroyed. Operations such as zoom-in, move, copy, and rotate make this process easy and accurate.

Next, the user will add any damage and/or movement cues necessary to meet the training objectives. In the case of the crash, the user may choose to depict the aircraft as damaged and may add smoke, additional rubble and debris scattered about. If a lot of rain had been received in the area, the user may add deep vehicle tracks through the middle of a field leading to the crash site to indicate that rescue operations will be difficult.

The SIGS operator can include a variety of atmospheric effects in the synthetic image, including snow, fog, and haze. In the airfield crash scene, it may be important to create a synthetic image as it would be seen in the middle of a sunny day, and then a second image as it would be seen if fog rolled in. Weather can certainly affect a rescue mission!

Lastly, the SIGS operator can specify the image size, camera angle and the sun angle (time of day). SIGS generates the photorealistic image containing all of the specified effects in 1–2 minutes.

Flexibility

As described in the previous sections, SIGS is a very flexible software package for creating a wide variety of synthetic images. When used with the appropriate aerial photographic databases and 3D object models, SIGS can be used for many training scenarios to achieve a variety of training objectives.

SIGS offers the flexibility to create a set of images to support a specific training scenario and then easily tailor the images as the training event proceeds.

SIGS images can help to answer such questions as:

- What if the plane crashed on the west side of the pier instead of the east side, where the water was deeper?
- What if fog rolled in?
- Where should the emergency equipment ideally be located?

An Example Scenario for Training Realism

This section outlines a possible scenario for use in an emergency management exercise including synthetic images generated by SIGS. The scenario covers a civilian airliner crash at Boston's Logan International Airport. An existing aerial photograph of Logan (Figure 4) was processed and integrated into the SIGS database. All the images used in the scenario were based on the Logan aerial photograph. Each image took approximately 15 minutes to edit and generate. This section includes a "what if" provision to the original scenario including SIGS synthetic images. The "what if" scenario has the airliner located in a different portion of the airfield where the challenges of response, rescue, or recovery are different.

Scenario 1: Image 1

This image of Logan (Figure 4) and surrounding areas provides an overview of the airport and surrounding environments including residential areas, industrial areas, beaches, salt marshes, and the harbor. This image provides for orientation of the overall area and displays the spatial relationship between the airfield and the surrounding transportation routes and populated areas. This could be a historical image acquired prior to the actual incident.

Scenario 1: Image 2

This medium-resolution image (Figure 5) depicts the site of an early morning crash of a DC-10, immediately after the incident. Upon approach for a landing, the aircraft landed in the water short of Runway 33L. This image indicates the grade and type of shoreline as well as the distance from the aircraft to the shore. This information would be important in determining the type of rescue equipment and the optimal access point.

Figure 4 Scenario 1: Image 1

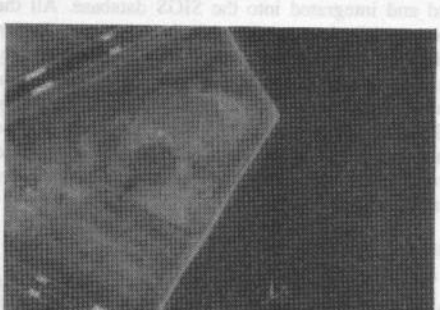

Figure 5 Scenario 1: Image 2

Scenario 1: Image 3

This high-resolution image (Figure 6) depicts the crashed airliner immediately after the early morning incident and the immediate surrounding area. From this image, the overall condition of the aircraft can be determined, including extent and specific location of damage. Such details of the structural damage could influence the type of equipment utilized in the rescue.

Scenario 1: Image 4

This medium-resolution image (Figure 7) depicts the crash site in mid-day, some time after the incident occurred. Rescue equipment is in place and passengers have been removed from the aircraft. The image provides an overview of the location of the rescue equipment and enables a reassessment of their placement to facilitate further operations. Post-incident analysis could determine if different positioning would have facilitated rescue efforts.

Scenario 2: Image 1

This medium-resolution image (Figure 8) represents a modification of Scenario 1 and depicts the site of the crash of the DC-10 immediately after the incident. Upon approach for a landing, the aircraft landed in the water between of Runway 27 and Runway 22L. This image indicates the grade and type of shoreline as well as the distance from the aircraft to the shore. This scenario is significantly different from Scenario 1 in that the aircraft has landed in a tidal flat where the water is shallow and the substrate soft and muddy. In addition, the effect of

Figure 6 Scenario 1: Image 3

the incoming tide on the stability of the aircraft and the accessibility may be taken into account. The rescue and recovery equipment and techniques would be different from that employed in Scenario 1 where the aircraft landed in deep water close to a rocky shoreline.

Scenario 2: Image 2

This high-resolution image (Figure 9) depicts the crashed airliner immediately after the incident and the immediate surrounding area. From this image, the overall condition of the aircraft can be determined, including extent and specific location of damage. In addition, the image can provide an indication of channels that would allow access by boats.

Scenario 2: Image 3

This medium-resolution image (Figure 10) depicts the crash some period after the incident occurred. Rescue equipment is in place and passengers have been removed from the aircraft. The image provides an overview of the

Figure 7 Scenario 1: Image 4

Figure 9 Scenario 2: Image 2

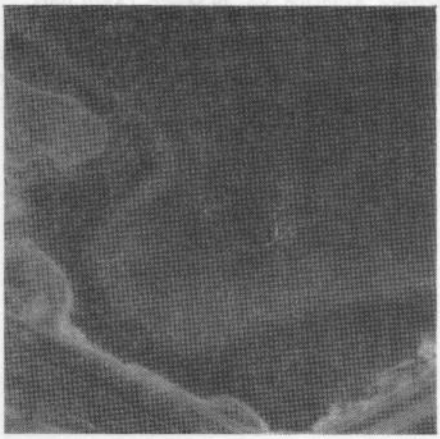

Figure 8 Scenario 2: Image 1

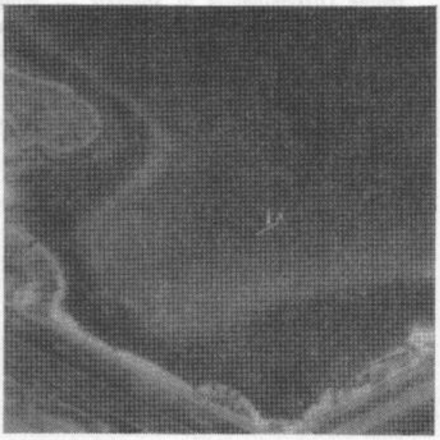

Figure 10 Scenario 2: Image 3

location of the rescue equipment and provides for a reassessment of their placement to facilitate rescue operations. Secondary analysis may indicate that a different evacuation route would have been more efficient in getting the passengers to shore and to awaiting ambulances.

Synthetic Images in Emergency Training — Implementation Challenges

Our development of synthetic imagery systems has concentrated to date on military exercise scenarios. In these cases the imagery has been an add-on to the large-scale training deployments of personnel and equipment with which the military has vast experience. We see several implementation challenges when converting this technology to use in civilian emergency management training:

- *Exercise Scripting for Effective Use of Imagery* — Desktop exercises will have to be made more dynamic and new scripts will have to be tailored to fit the training scenario. Scenario developers and trainers will have to better understand the capabilities of synthetic imagery and factor the strengths into their exercises.
- *Image Generation Realism and Speed* — Image realism may have to be different for some emergency training situations. Disaster-related (rather than combat-related) objects will need to be added to the SIGS object library and more detail may be required for close-in views of emergency targets. And, of course, users will ask for image generation times in seconds rather than minutes.
- *Image Dissemination to Students* — While traditional desktop exercises require everyone to be in the same room at the same time, video-conferencing, and collaborative computing technologies could support dispersed participants in an exercises. In fact, consideration should be given to having the exercise, with all associated synthetic imagery, run with the players located at their normal operational bases or in mobile vehicles.
- *Image Display During Training* — How the synthetic imagery is displayed during the exercise can influence the training impact and value. Large-screen displays may be suitable for top-level decision-makers but other participants will need a range of displays from laptop computers in vehicles to personal desktop displays.

A final challenge will be determining the extent that synthetic imagery technology can contribute at the various management and operational levels involved in emergency management training. While overview imagery may be useful for the orientation of agency and department-level executives, emergency managers at the command and team level will demand more detail, more scenario options, and faster response to scenario changes. As we continue our development of the SIGS system and its integration into civilian emergency management training these challenges will be at the forefront.

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ENVIRONMENTAL EQUITY AND INDUSTRIAL CHEMICAL ACCIDENTS

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ABSTRACT

Concerns about environmental equity to date have focused almost exclusively on undesirable land uses and chronic health hazards associated with pollution, especially air pollution. In contrast, this analysis deals with the acute hazards associated with storing extremely hazardous substances in industrial facilities. These chemicals have the potential to form toxic vapor clouds when accidentally released. Using EPA's technical guidance for hazard analysis, the degree of spatial vulnerability to such accidents is estimated for various socioeconomic groups in Allegheny County, Pennsylvania. The results show that minorities and the poor are more vulnerable than others, with race being a somewhat more influential factor than income.

INTRODUCTION

This paper examines the issue of environmental equity in the context of industrial hazards in urban areas, a topic that has received considerable attention recently [Mohar and Bryant (1), Napton and Day (2), *National Law Journal* (3)]. The hazard of concern here is the storage of certain chemicals which, if accidentally released, might result in the formation of toxic vapor clouds that would spread to residential communities. The area of interest is Allegheny County, Pennsylvania, where the major industrial city of Pittsburgh is located. The environmental equity issue is whether certain disadvantaged members of the public bear a disproportionate share of the hazard burden. We have chosen to study this issue by comparing, in a spatial sense, the vulnerability of African American residents and the residents of lower income households with the vulnerability of other residents of the county. Available data on the location and characteristics of the county's facilities and population are analyzed with a geographical information system (GIS). The facility data are the 1992 Section 312 (Tier II) reports that industry submits to comply with the provisions of the 1986 Emergency Planning and Community Right to Know Act (EPCRA), which is also known as SARA Title III. The population data come straight from the 1990 U.S. Census files.

A circular vulnerability zone is derived for each reporting facility, the size of which depends on the toxicity and the quantity of chemicals stored there. The procedure for generating these circles is adapted from EPA's technical guidance on hazard analysis (summarized in the next section) and uses CAMEO software as recommended by the agency. The level of vulnerability is assumed to be uniform throughout each zone and constant from one zone to another. As a measure of the combined vulnerability of any socioeconomic group to accidental releases occurring at any facility in the county (i.e., the group's hazard burden), we introduce the notion of "average vulnerability intensity" (AVI). The AVI value for any such group indicates the degree to which the vulnerability zones overlap the areas where those people reside. The level of equity between any pair of socioeconomic groups of interest is then reflected by the relative difference in their AVI values.

EPA'S TECHNICAL GUIDANCE

According to the EPA technical guidance publication known as the "Green Book" [USEPA (4)], the analysis of vulnerability proceeds in two steps: screening and reevaluation. In the *screening* step, a vulnerability zone based on worst case assumptions is calculated for each of the facilities in the area of concern. The zones, which ideally ought to be shaped in a way that reflects the formation of a plume in the direction of the wind, are drawn instead as circles because the wind direction at the time of release is unpredictable. A risk-based ranking of the facilities is then produced, based on the probability of release for each facility and the population in its zone. During the *reevaluation* step, new vulnerability zones are calculated for the top-priority facilities, using facility-specific data to generate more realistic descriptions of the most probable release scenarios.

The size of a vulnerability zone depends on four major factors: (1) quantity and rate of release, (2) meteorological conditions, (3) surrounding topography, and (4) level of concern (the concentration of a released chemical in the air above which there may be serious irreversible health effects or death as result of a single exposure for a relatively short period of time).

In the screening step, the vulnerability zone's radius is based on the maximum quantity that could be released from the largest vessel in the facility within 10 minutes for a solid or gas, or one minute for a liquid, assuming a wind speed of 1.5 meters per second (3.4 mph) and very stable atmospheric conditions (stability class F). The surrounding topography is assumed to be that of a rural area (i.e., flat, unobstructed terrain) and the level of concern is assumed to be one-tenth of the IDLH concentration.

In determining the vulnerability zones to use in the equity analysis, we followed the technical guidance for the screening step in every respect but one: since we are dealing with a large metropolitan area, we assumed the topography to be urban rather than rural. Then, since the results of the screening step are only considered to be valid when the radius of the zone is between 0.1 mile and 10 miles, inclusive, we ignored the results for all radii below this range and truncated to 10 miles all radii above it. We did not perform the reevaluation step.

VULNERABILITY ZONES

The 1992 Section 312 (Tier II) reports for Allegheny County, obtained from the Pennsylvania Department of Labor & Industry, Bureau of Right to Know, reveal that a total of 867 facilities stored a total of approximately 1750 chemicals. Of these facilities, 176 reported at least one extremely hazardous substance (EHS). EPA considers these chemicals to be the ones most likely to have severe toxic effects on human beings exposed to an accidental release. On closer inspection, we found that some of the chemicals reported by these facilities were incorrectly marked as EHSs. After eliminating them we ended up with only 128 facilities reporting a total of approximately 120 different EHSs.

For each facility we used CAMEO to calculate a vulnerability zone for each EHS stored there and then selected the largest resulting circle. The amount of each of these chemicals that might accidentally be released at each facility was assumed (conservatively) to be the midpoint of the range of the daily average amount reported.

In the first round of CAMEO calculations, almost half the cases entered could not be handled by the program for lack of a "liquid factor" value for incorporating the molecular weight and vapor pressure of a liquid chemical into the release rate equation. CAMEO's chemical database includes such values for substances that are liquid at ambient temperature and pressure. However, since many of the reporting facilities either store their chemicals at other than ambient conditions or incorporate them in mixtures, substances that are not usually stored as liquids had to be treated as such. In the next round, we calculated the liquid factors for these substances using Appendix G of the Green Book, which gives equations for liquid factors in ambient conditions, at boiling point, and at melting point. The molecular weights, vapor pressures, and boiling temperatures needed for these equations were taken from a table of EHS properties in Appendix C, supplemented by information in Section D of the *Handbook of Chemistry and Physics* [Chemical Rubber Company (5)].

Of the 128 facilities considered, only 62 turned out to have a vulnerability zone radius of at least 0.1 mile. The distribution of these radius lengths is presented in Table 1. Figure 1 shows the locations of the 62 facilities, many of which are located on one of the three major rivers in the county.

Table 1. Radii of vulnerability zones for facilities storing EHSs in Allegheny County

Radius (miles)	No. of Facilities
0.10 - 0.99	12
1.00 - 1.99	16
2.00 - 2.99	8
3.00 - 6.99	0
7.00 - 7.99	4
8.00 - 8.99	1
9.00 - 9.99	0
10.00	21

THE GIS ANALYSIS

In the context of the acute hazards considered here, environmental equity relates to how the spatial vulnerability of minorities compares to that of non-minorities and how the spatial vulnerability of low-income groups compares to that of higher-income groups. To obtain the numbers required to make such comparisons, we used Atlas GIS software to superimpose the vulnerability zones on each of the block groups in the county and to examine the socioeconomic attributes of the population in the intersecting areas. Block groups are spatial divisions defined by the U.S. Census Bureau; in Allegheny County, their average size is about 0.5 square miles. Three types of data files were needed for the GIS analysis: (1) geographic files for mapping the areas of interest, (2) a datapoint file for locating the facilities of concern, and (3) attribute files for associating sociodemographic data with the intersecting areas.

The geographic files, including the TIGER file, were obtained from the U.S. Census Bureau. The datapoint file was constructed from the Section 312 reports, except when the latitude-longitude coordinates were not provided, in which case the street address was "address-matched" to a pair of coordinates using a function built into the software. Any addresses that were not recognized were assigned locations based on telephone calls to the facilities. A circle representing the vulnerability zone was then plotted around each facility. The attribute files were constructed using 1990 Census data on race and income (STF1A and STF3A). Block groups were selected as the unit of spatial analysis because smaller units (blocks) would have required more computational without adding much meaningful precision, while larger units (census tracts) might have blurred important spatial distinctions.

The first step in the analysis was to generate an indicator of the total vulnerability of each block group by finding the area it has in common with each of the 62 vulnerability zones and summing up those areas. This is an appropriate indicator, assuming that being exposed to *n* equal hazards is *n* times worse than being exposed to any one of the hazards alone. To put these resulting areas in relative terms, we then introduced another notion, the *vulnerability intensity (VI)* of a block group, which is the ratio of this area to the total area of the block group. The corresponding formula for this calculation is

$$VI_i = (\Sigma_j a_{ij}) / A_i$$

where a_{ij} is the area that block group i has in common with the vulnerability zone of facility j, and A_i is the total area of that block group.

The *average vulnerability intensity (AVI)* for any given racial or income group depends on the number of individuals or households of that type in each block group and on the corresponding values of VI_i. It is calculated for the county as follows:

$$AVI_k = \Sigma_i [(N_{ik} / \Sigma_i N_{ik}) \times VI_i]$$

where N_{ik} denotes the number of individuals or households of type k in block group i. The AVI may be thought of as an indicator of "individual" vulnerability, since it is simply the average number of vulnerability zones in which each individual resides.

The equity issue thus reduces to comparisons between (a) the AVI value for the racial or income group of concern and (b) the AVI value of the corresponding reference group. For example, if equity with respect to race is the issue and the group of concern is African Americans, then the reference group could be whites. Or if equity with respect to income level is the issue, then the group of concern is individuals with family incomes below the poverty line or below the median income for the county, and the reference group could be individuals with incomes above the poverty line or above the median income for the county.

RESULTS OF CALCULATIONS

The results of the AVI calculations appear in Table 2. An AVI value is given for Allegheny County as a whole, for African Americans alone, and for whites alone. AVI values are also given for the individuals within each of these groups who live below the poverty line ($12,674 in annual income for a family of four in 1989) or above it. The poverty-related figures in the table do not account for anyone who is not in the "povery sample," i.e., anyone who is institutionalized or lives in a military barracks or a college dorm. Taken as a whole, the county has an AVI value of 12.5. That is, the average resident lives within 12.5 of the vulnerability zones calculated for the Section 312 facilities which store EHSs. If this is seems high, it is because EPA's technical guidance for screening analysis, which was developed for emergency planning purposes, generally results in a conservatively large value for the size of a vulnerability zone.

The AVI values in the table show that, on average, poor people are more vulnerable than other people (14.4 vs. 12.2) and African Americans are more vulnerable than whites (15.8 vs. 12.0). The worst-off group is African Americans living below the poverty line (16.2). Thus, poor African Americans tend to be more vulnerable than other African Americans (15.6). Similarly, poor whites (13.4) tend to be more vulnerable than other whites (11.9). However, race is a more dominant factor than income level, as evidenced by the fact that, on average, even African Americans above the poverty line are more vulnerable than poor whites (15.6 vs. 13.4).

Table 3 shows in percentage terms the relative differences in these AVI values, depending on whether the comparisons are made by race or income level. The first comparison shows the greatest disparity: a relative difference of 31% between the average vulnerability

Table 2. AVI values in Allegheny County by race and income level

	Number of persons	AVI
Total population	1,336,449	12.5
Above the poverty line	1,154,460	12.2
Below the poverty line	150,713	14.4
White population	1,169,452	12.0
Above the poverty line	1,049,914	11.9
Below the poverty line	95,317	13.4
African American population	149,550	15.8
Above the poverty line	92,544	15.6
Below the poverty line	51,712	16.2
Total households		
Median household income at or above the county median		11.6
Median household income below the county median		14.4

Table 3. Relative differences in AVI values

Comparison by race: African Americans vs. whites	
For all county residents	31%
For county residents living below the poverty line	21%
Comparison by income level: living below the poverty line vs. living above it	
For all county residents in the poverty sample	19%
For all whites in the poverty sample	12%
For all African Americans in the poverty sample	4%

of African Americans and whites in the county. With a value of 21%, the second comparison shows that the relative difference between poor African Americans and poor whites is somewhat less. When the comparisons are based instead on whether the income level is below or above the poverty line, we find that the average vulnerability of all the poor county residents is 19% higher than it is for other county residents, which is less than the relative difference based on race.

Since the poverty line only separates the *very* poor from the rest of the population, we also examined differential vulnerability according to income level using median household income as the dividing line instead. Allegheny County had a median household income of $28,136 in 1989. We calculated two additional AVI values: one for all block groups with a median household income below that level, and another for the remaining block groups in the county. They turned out to be 14.4 and 11.6, respectively, for which the relative difference is 24%. This is larger than the relative difference of 19% associated with the poverty line, indicating that the class difference is even greater between the lower half and the upper half of the economic ladder than it is between the poor and the "not poor." In other words, for the acute hazard of concern, inequity as a function of income level is not limited to the very poorest residents.

Finally, since the oldest and youngest members of the public are generally considered to be more sensitive than others to the hazard of toxic inhalation and less capable of self-protection in the event of a release accident, we calculated AVI values for these groups, too. The resulting values, which were only slightly different from the overall value of 12.5 that applies to all county residents, turned out to be 12.3 for ages five and younger (100,509 people) and 12.9 for ages 65 and older (231,911 people).

For mapping purposes, we also calculated AVI values by block group, regardless of racial composition and income levels. The results, as seen in Figure 2, lead to an interesting pattern in which the vulnerability tends to be highest near the center of the county and declines in bull's-eye fashion as one moves away from the center in any direction. To some degree, this is due to a higher density of facilities near the center, but for the most part it is attributable to the fact that more of the larger-radius vulnerability zones overlap near the center of the county than further from its center. For comparison, Figure 3 shows by block group what percentage of the population is African American. Figure 4 does the same for the percentage of the population that lives below the poverty line in each block group.

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Figure 1. Facilities storing EHSs in Allegheny County

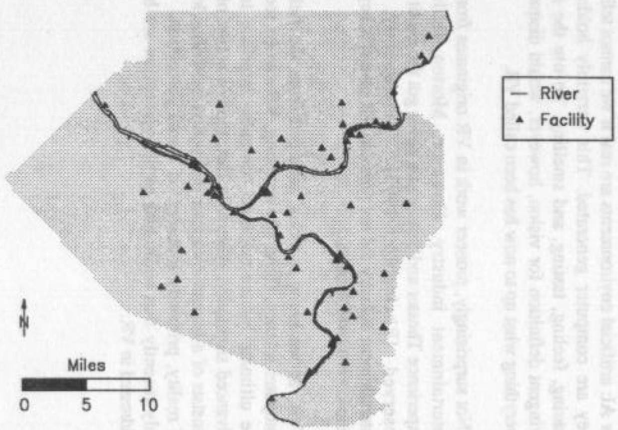


Figure 2. Average vulnerability intensity in Allegheny County block groups

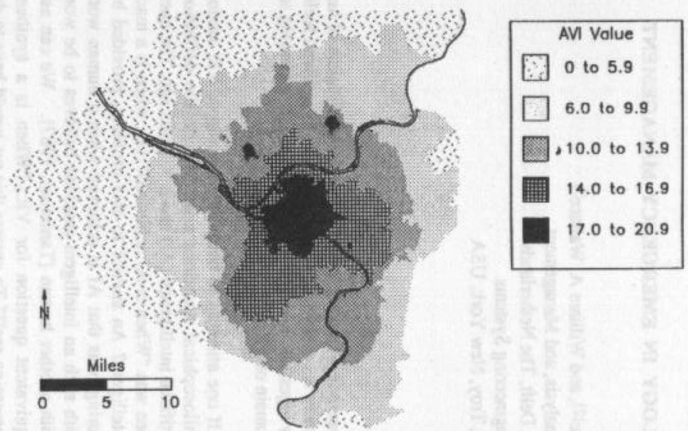


Figure 3. Percent African Americans in Allegheny County block groups

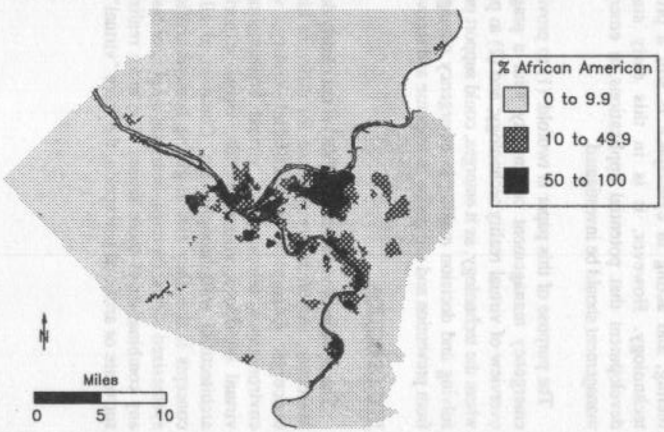
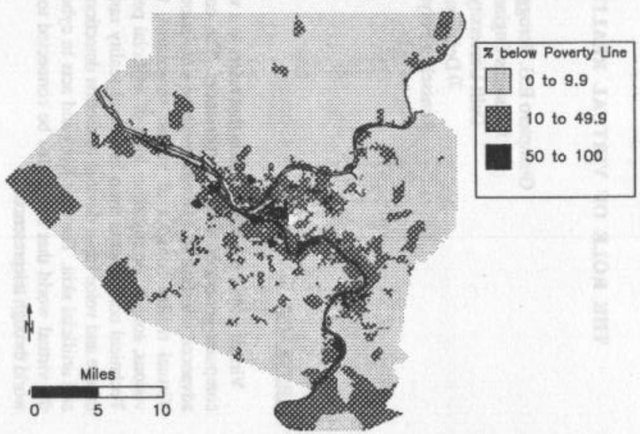


Figure 4. Percent of population below the poverty line in Allegheny County block groups



THE ROLE OF VIRTUAL REALITY TECHNOLOGY IN EMERGENCY MANAGEMENT

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ABSTRACT

Virtual reality is a popular term that refers to a variety of computer-generated virtual experiences. The core is an advanced interface to a human-machine simulation system. Virtual reality consists of virtual sensations, feelings, visions, sounds, or any other kind of artificial perception. Technical components used in virtual reality range from mouse and voice input devices to motion detection systems and artificial skin. The user lives and acts in cyberspace - the virtual world that could also be connected to the real world through telepresence.

The field of virtual reality is still in its infancy. Moving, feeling, and acting in cyberspace is still a primitive technology. However, it is in this early stage of development that potential applications in emergency management should be investigated.

The purpose of this paper is twofold: (1) to provide the emergency management community with a pragmatic overview of virtual reality technology; and (2) to propose where the technology, as it emerges, could support problem solving and decision making in emergency management from prevention and mitigation to response and recovery.

INTRODUCTION

The domain of virtual reality (VR) is not clearly defined. Moreover, similar terms are used for different kinds of concepts. Examples are artificial reality, virtual environments, telepresence, virtual instrumentations, virtual interfaces, virtual worlds, virtual experiences, architectural walkthroughs, etc. Common to all these concepts is that they aim at giving humans artificial or synthesized views, feelings, hearings, smells, or tastes, or any combination of these senses. The more realistic the surrogate or artificial perception, the more "virtual" is the approach. However, only the genuine stimulation of human senses is considered VR; the creation of "artificial feelings" by ingestion, injection, or inhalation does not belong to the domain of VR.

If one attempts to bound the domain of VR, analogous philosophical questions arise as with the definition of artificial intelligence (AI) about 30 years ago. The question then was "When is AI achieved?" i.e., when is a machine intelligent? An answer to this problem, provided by A. Turing, was that AI is achieved when a human working with such an intelligent machine believes to be working with another human [Tanimoto, 1987]. We can ask an equivalent question for VR: "When is a synthesized perception real?" To answer this we would have to define "reality." For some senses we can use the same definition as for AI: artificial environments are real if we cannot tell that they are computer generated. This certainly holds for hearing, feeling, tasting, and smelling. To use the same stringent definition for vision, however, would disqualify everything what up to now has been called VR.

Not surprisingly, pioneer work in VR originates from the entertainment industry. However, Morton Heiling's Experience Theater and Sensorama never got the credit they deserved [Rheingold, 1993]. Consequently, the entertainment industry did not promote VR concepts beyond Cinescope movie theaters.

VR, as we know it today, emerged from the field of computer science. Generally speaking, VR can be seen as the ultimate human-machine computer interface to an advanced simulation system. In fact, today's notion of VR consists of a human-computer interaction at various levels of reality, primarily focusing on visual perception. It is only recently that audio and tactile perception are being addressed in VR.

VR is an immersive, synthetic, or computer-generated environment that provides the experience of being there [Rheingold, 1991]. Ideally, VR is intuitive as well, allowing he user to communicate with the system via familiar and obvious actions [Wells, 1992]. In discussing VR, it is important to distinguish between natural and synthetic experience. In a natural experience, the user directly perceives the properties of something that is physically present before the perceiver. By contrast, in a synthetic experience, the user perceives a representation of something physically real rather than the thing itself [Robinett, 1992]. Examples of synthetic experience include flight simulation, robot tele-operation, everyday telecommunication, and, of course, virtual reality. Synthetic experience may be generated by the physical world, as in telepresence (using virtual reality to perceive and manipulate a objects remote in space from the user) or it may be generated by computer, as in architectural walkthroughs (using a VR version of an architechtural blueprint, the user can walk through a building that does not exist in the physical world). We have identified three levels of virtual reality: virtual space, virtual image, and virtual environment. Virtual space uses pictorial cues to represent a 3D portrayal on a flat (2D) display. These displays commonly use perspective, shading, and textual gradient to create a 2 1/2D image. Virtual images are perceived by adding various stereoscopic cues to produce 3D displays. Virtual environments add other sources of information with audio and tactile images [Wallace, 1992].

COMPONENTS OF VIRTUAL REALITY

The basic component of VR is the human-machine interaction in a virtual space, also called cyberspace. In addition to the above mentioned output capabilities of VR systems, input devices through which the human conveys information to the machine add significantly to the sensation of VR. The ultimate goal for input devices is certainly to reach the same realism as aspired for output devices; i.e., voice, motion, and facial expression could be understood by the machine as they are by another human.

Virtual Worlds and Cyberspace

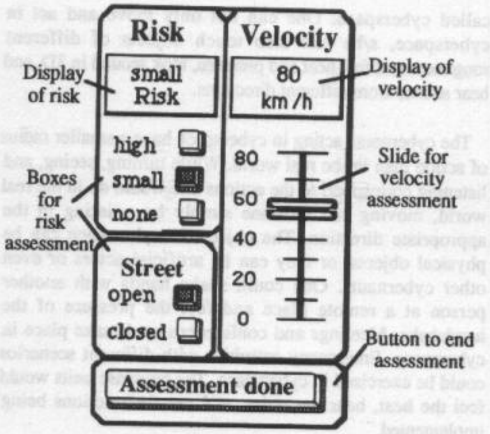
A virtual world is a place that generates events that never really happen. It consists of a computer generated environment that a user interacts with. In more advanced systems, the user can even see him/herself acting in this environment. The use of computers coupled with automatic machinery to control and carry out complex operations is called cybernation. Consequently, virtual worlds are also called cyberspace. One can not only move and act in cyberspace, s/he can also touch objects of different roughness and feel heat and pressure, look around in 3D, and hear sounds from different directions.

The cybernauts acting in cyberspace have a smaller radius of action than in the real world. While turning, seeing, and listening correspond to the actions one would do in the real world, moving can be done simply by pointing in the appropriate direction. The objects in cyberspace can be physical objects, or they can be artificial actors or even other cybernauts. One could shake hands with another person at a remote place and feel the pressure of the handshake. Meetings and conferences could take place in cyberspace. Emergency activities with different scenarios could be exercised in cyberspace. The response units would feel the heat, hear the noise, and see their actions being implemented.

Although these VR scenarios sound quite visionary, the technology to make them happen is becoming accessible, and time has come to investigate the potential use for emergency management. Many concepts of VR are already being implemented in emergency management.

Technology in VR

A major breakthrough in visual interactive input devices was reached in 1984 with the computer mouse system by Macintosh. The desktop represents a work place with disks, folders, and files as virtual objects. The mouse represents the virtual hand or finger which is used to point to those objects on the desktop. Single pointing to the objects selects the object and double-pointing opens the object. Objects can be moved around on the desktop and also be inserted into other objects. Since 1984, the mouse-pointing interface has been further developed to include virtual instruments, such as slide bars, knobs, toggles, and radio buttons. The input has become increasingly intuitive because the user knows from experience in the real world how to handle those virtual devices. Instead of using his/her hands and physical instruments, s/he uses the mouse as the virtual hand to work with the computer generated virtual input device, as illustrated below.



Still at the front of commercial microcomputers, a major new breakthrough in input devices has been reached just this year. The new Macintosh Centris and Quadra systems are equipped with remarkably effective voice recognition and voice synthesis features. Although there are not yet many software packages that can handle voice input, it will be only a matter of time until software houses start taking advantage of this novel input device. Soon we will be talking to our word processor and spreadsheet programs.

The devices most frequently associated with VR in these days are head mounted 3D displays and gloves. Three dimensional vision can only be achieved by providing the two eyes with different pictures that can be merged by the human brain to one 3D picture. This artificial 3D vision is called stereoscopic viewing.

More important than 3D perception from a motionless source, as is the case with 3D cinemas, is 3D vision that follows the user s head movements. This allows one to look around (or even walk around) the corner of an object in cyberspace. This 3D vision is achieved by head mounted cameras that keep track of the head position in space. In a somewhat more restricted way, this effect can also be achieved by 3D glasses, coupled with an appropriate simulation system.

Gloves are used as advanced input devices. Sensors attached to the glove determine the relative position of the fingers and the glove in space. One can use the glove to move around in cyberspace, but also to pick up and move around objects. Advanced gloves include the possibility of tactile perception; i.e., the glove can simulate pressure, heat, and the feeling of touching a rough or smooth surface. The ultimate goal in tactile output devices are suits that can act as artificial skin.

More advanced input devices are currently subject of research. They include lip reading devices, gestural input devices, eye-movement detectors, and facial motion detectors. Anything the user does in front of the computer will be detected by sensors, used as input, and processed in the program. While so far only active inputs such as a mouse click can be perceived by the system, advanced computer systems will also be able to recognize and process passive input, such as the facial expression for sadness. These advanced input capabilities coupled with the sophisticated 3D output systems will ultimately create what is known as mind amplifying computer technology - virtual reality.

The Role of Information Technology

The key to VR is advanced computing and communications technology. For every move or other kind of input, the simulation generates new graphs. Advanced microcomputer-based VR systems can generate from a couple of thousand texture-mapped polygons up to several thousand flat-shaded polygons per second. Power is provided today by the most advanced microcomputer systems, and in the near future it will be provided by RISC-based (reduced instruction set computers) microcomputers developed by Apple and IBM.

Data transfer between remote and mobile actors can be achieved by satellite-based phone systems, such as Iridium by Motorola. Eventually at least 60 satellites will provide world-wide communications capability. In addition, fibre optics systems will transmit data at a speed equivalent to 50,000 typed pages per second. The Global Positioning System (GPS) and other satellite tracking and communications systems such as OmniTrac, EutelTrac, and Inmarsat C provide accurate positioning and real-time data transfer between any two locations on earth.

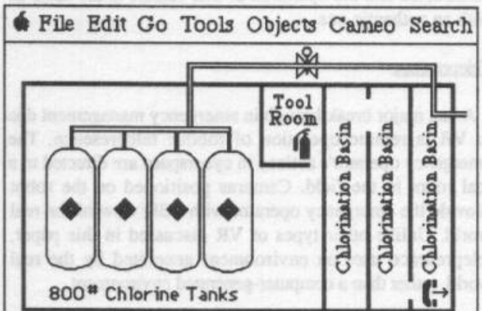
IMPACT ON EMERGENCY MANAGEMENT

VR has already had significant impact on emergency management, including advanced data visualization systems within geographical information systems (GIS). Many advanced decision support systems (DSS) for emergency management rely on GIS technology and virtual instrumentations. Dispersion plumes are depicted on digitized backgrounds of areal pictures and the growth of the plume is simulated and visualized in real-time. Concepts more closely related to today's notion of VR are virtual world navigation, tele-virtual conferencing, telepresence, and simulation in cyberspace.

<u>From CAMEO to Virtual World Navigation</u>

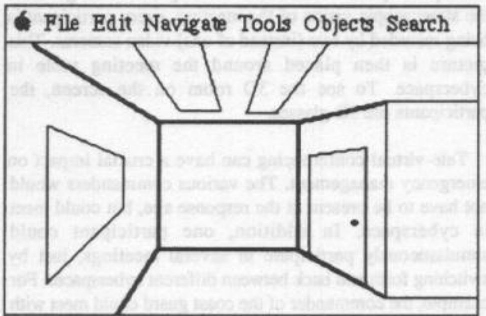
A widely used emergency response DSS is CAMEO, developed by the U.S. National Safety Council. It originally was developed on a hypermedia system on a Macintosh computer. The advantage of hypermedia is that its object oriented graph structure that allows easy navigation through the system. In addition, hypermedia systems are often used as authoring tools for multimedia systems. Objects can be text, graphics, drawings, figures, or even environments. Hypermedia systems are used for all kinds of applications. Besides multimedia applications, they are also used for simulation. An example is the decision support system for hazardous material transportation and emergency response in hypermedia [Beroggi and Wallace, forthcoming].

The concept of hypermedia has recently been used in conjunction with VR [Smith and Wilson 1993]. Instead of navigating through map displays as embedded into CAMO (see first figure below), the emergency managers would navigate through virtual environments (see second figure below). These virtual environments give a better comprehension of the facility one is walking through. This is another example of architectural walkthrough. However, emergency managers working with a hypermedia system would have the capability to "jump" to any other piece of the facility or the environment.



Navigation through Design Maps

Adding 2D monoscopic or 3D stereoscopic vision and 2D or even 3D sound has the potential to improve significantly the user s perception of the situation. Emergency managers who have to enter a burning or contaminated building could first analyze the lay-out and the escape routes of the building.



Navigation through Virtual Environments

For most tasks, a slide view of the virtual environment might be sufficient. However, some emergency management situations could call for continuous real-time simulation. Commercial software systems are available for continuous VR simulation. An example is the Windows application WorldToolKit from SENSE 8 Corporation, which has a library of over 400 functions to create real-time interactive 3D simulations. The user can create stand alone applications that use Excel or Lotus files.

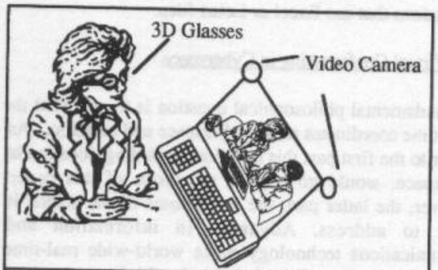
<u>Tele-Virtual Conferencing in Cyberspace</u>

A fundamental philosophical question is to ask what the space-time coordinates are of cyberspace and its actors. An answer to the first part this question, regarding location in cyberspace, would go beyond the scope of this paper. However, the latter part, the coordinates of the actors, is easier to address. Advances in information and communications technology make world-wide real-time communications possible. Information highway systems, satellite communications systems, and increasing computing power allow remote and mobile actors to join a communication meeting at any time in cyberspace.

Commercial tele-conferencing systems provide each participant with a view of all the other participants in different windows. However, despite the availability of this artificial tele-conferencing environment, real world meetings still seem to be preferred. Consequently, only environments that closely emulate real world scenarios might have a chance to be preferred to face-to-face meetings: tele-virtual conferencing [Ramanathan et al. 1992].

In tele-virtual conferencing, each participant sees the other participants in the same meeting room. To generate the stereoscopic vision of the meeting, every participant is being recorded by two (instead of one) video cameras. This picture is then placed around the meeting table in cyberspace. To see the 3D room on the screen, the participants use 3D glasses.

Tele-virtual conferencing can have a crucial impact on emergency management. The various commanders would not have to be present at the response site, but could meet in cyberspace. In addition, one participant could simultaneously participate in several meetings, just by switching forth and back between different cyberspaces. For example, the commander of the coast guard could meet with the on-site response team and instantaneously switch to his/her on-scene commanders to implement further actions. Furthermore, a commander would not even have to be positioned at a headquarters for a meeting in cyberspace. S/he could be travelling on a plane and working with a notebook with two small cameras attached at the corner of the notebook. Putting on his/her 3D glasses and ear-phones puts him/her, via satellite communications, right on the scene. The figure below shows the concept of mobile tele-virtual conferencing.



Mobile Tele-Virtual Conferencing

Training in Cyberspace

The success of an emergency operation depends to a large extent on the training the emergency responders have had. Training today means exercise with real situations, such as in nuclear power plants, fire-fighter training, emergency responder training, driver of HazMat training, and many more. Although the objects, trucks, roads, hydrants, etc. are real, the sensation of a real emergency situation is difficult to imitate.

Training in cyberspace would not focus on handling devices, shutting down engines, or applying first-aid techniques to people. It would focus on finding ways to get through a building, finding the location of hydrants, locating sensitive devices, and finding a way through smoky rooms.

Different scenarios could be devised, focusing on different types of emergency situations, such as emergency responses in contaminated nuclear plants and environments or fire-fighting under dense smoke. While the trainees act under difficult conditions such as restricted visibility and breathing problems due to smoke, the trainers could stand next to them in a "clear" cyberspace (i.e., without the artificially generated impacts due to the smoke) and control their actions and advice them. At any time of the simulation, the trainers can change the environment of the cyberspace; e.g., create more or less smoke, increase the temperature, make a building fall apart, or switch instantaneously from summer to winter.

Another application of VR in training is already being implemented and uses simulators similar to flight simulators. The emergency responder, usually a driver of a vehicle, moves in cyberspace. Vision, sound, and motion are simulated. The trainer can change at any time the conditions of the cyberspace to test or assess his/her behavior. For such purposes, a real vehicle is usually constructed and the operation of that vehicle is the same as with an authentic one.

Telepresence

A last major breakthrough in emergency management due to VR is remote operation of robots: telepresence. The emergency operator's actions in cyberspace are directed to a real robot in the field. Cameras positioned on the robot provide the emergency operator with a 3D view of the real world. Unlike other types of VR discussed in this paper, telepresence uses an environment generated by the real world, rather than a computer-generated environment.

An example of an advanced telepresence device is a suit that an emergency manager would wear. This suit would transform the emergency manager's actions directly into the robot's actions: the emergency managers and the robot merge in cyberspace.

Applications of telepresence include activities in environments posing physical hazards to human emergency responders, such as sinking ships, earthquake areas, or areas that have been radioactively or chemically contaminated.

CONCLUSIONS

The significance of virtual reality has been recognized. Interactions in cyberspace, telepresence, navigation in virtual worlds, and tele-video conferencing have become viable technologies. However, the role of virtual reality in problem solving and decision making must be addressed in the context of the problem at hand. This paper introduced some of the uses of virtual reality in emergency management.

Both the research community and people working in the field have begun to appreciate the potential of virtual reality. New methodologies to improve decision making and problem solving in emergency management will emerge shortly. However, any proposed analytical paradigm must be assessed by gaming or in an experimental setting. Only such a thorough assessment can provide significant insights that can be used to design virtual reality decision support systems (VRDSS).

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NATIONAL LABORATORY EFFORTS IN EMERGENCY MANAGEMENT

GIS FOR SAFETY OF FOREIGN NUCLEAR FACILITIES

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ABSTRACT

A GIS can be a valuable tool in *ex post facto* analyses of concerns related to plant siting as information captured in the GIS can be used to effectively manage risk and to properly prepare resources for accident response. The Office of Foreign Intelligence (OFI) of the Department of Energy (DOE) is developing a GIS-based Foreign Intelligence Nuclear Information System (FINIS) to respond to requests for information and support from US policy makers within 24 hours of a notice of an incident at a foreign civil nuclear reactor. Ideally, the GIS would contain information based upon a probabilistic risk assessment (PRA) of each of the more than 300 foreign reactors. However the cost and duration of performing PRAs makes this impractical. To identify for capture in the GIS the most important information on the most dangerous reactors, we used a methodology called the Vital Issues process (developed at Sandia National Laboratories) to involve key stakeholders in the use of both the GIS and its products in the identification of relevant information categories. This paper discusses the development of the FINIS.

IMPORTANCE OF MANAGING INFORMATION ON FOREIGN NUCLEAR REACTORS

The economic and environmental implications of the use of nuclear energy outside the US is a relatively new program within the Department of Energy's Office of Foreign Intelligence . The DOE has traditionally focused its resources on nuclear weapons and proliferation issues. However, following the Chernobyl accident in 1986, the US intelligence community began to focus on nuclear energy issues in addition to proliferation. The Chernobyl accident raised questions within the intelligence community about how well it was prepared to address nuclear safety issues and whether intelligence could help policy makers respond to future problems. The Vital Issues process - a strategic issue identification process initiated by OFI in FY 1992 - identified reactor safety as a key area for programmatic focus (Glicken and Engi 1992a, 1992b).

To this end, OFI has since committed itself to improving its support of US policy makers on nuclear energy issues in foreign countries. In 1991, a program was established dedicated to monitoring information on foreign nuclear power programs and to providing related warning information and analysis. The scope of interests of the Nuclear Energy Intelligence Program includes everything from markets for nuclear fuels to environmental issues arising from the handling and storage of nuclear wastes. The primary issue, however, is safety.

There are numerous parties - public and private, US and foreign, hostile and sympathetic - that are examining nuclear safety issues. OFI has neither the resources nor the desire to duplicate them. It is convinced, however, that intelligence could be contributing more to the study of nuclear safety issues overseas than it has. One of the key challenges OFI faces in doing so is determining how to maximize the use of its limited resources;

it needs to ascertain how to direct them towards the nuclear safety issues most needy of its attention and where intelligence is likely to have the greatest impact.

One of the key areas of OFI contribution is its support to federal policy makers (within DOE as well as other government agencies) through the timely provision of appropriate information. This requires that OFI has available to it the right information in a usable format when it is needed. OFI has recognized the role a geographic information system (GIS) could play in its support of policy makers in the event of a foreign nuclear reactor incident and has asked Sandia National Laboratories (SNL) to support it with the development of a GIS-based Foreign Nuclear Information System. In order to satisfy the requirement for the right information at the right time in a world of limited resources, there must be a credible and effective mechanism for identifying and prioritizing the 'right' information. SNL has used the Vital Issues process to do just that.

GEOGRAPHIC INFORMATION SYSTEMS

A GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. 1

The task of providing information relevant to developing an international response to a nuclear incident is heavily dependent upon the geographic location of the plant. Not only knowing the location, but being able to query and draw inferences from the results of those queries, is extremely useful. A GIS provides true topological reference data that permits those queries.

The GIS we are developing at SNL for OFI (the FINIS) will have an easy to use graphical user interface (GUI) which directs the user through pre-established queries, reports, and displays. There is also a possibility of performing ad-hoc queries as the sophistication of the users increase.

[1] ESRI, Inc. Redlands, CA.

The GIS can be expanded into a much more sophisticated decision support tool with the addition of a relational data base management system (RDBMS), statistical packages, simulators, and expert systems, which permit the incorporation of information that may not be strictly geographic.

Constructing the GIS

The application is a computer based system containing critical information, information that would be required by policy makers to respond within 24 hours to a nuclear accident. This system will provide access to information about geographically referenced foreign nuclear reactors. Additional textual information associated with a geographic feature will be included, e.g. reactor engineering information. The foreign nuclear reactor system GIS may then be used to answer questions relating to locations, conditions, trends, patterns, and will provide the ability to model scenarios through the use of menu-driven pre-defined queries. The three principal paper outputs of the system will be: 1) a two page summary of reactor engineering data and reactor event history, 2) a summary of the hypothetical consequences of a specific accident at a reactor, and 3) a map, on one page, of a 150 Km radius circle around the reactor showing key geographic features.

GIS is the core through which this information will be linked. It provides a topological referenced data set for the reactors which permits the inclusion of geographic features into the analysis of accident risk and consequences.

The system is configured to run on a SUN workstation using ARC/INFO as the GIS and Informix as the RDBMS. The map system relies upon the Digital Chart of the World (DCW) (scale 1:1,000,000) provided by ESRI from the Defense Mapping Agency.

The information content of the maps is constrained, in the near term, by the coverage of the DCW. A Joint Applications Design (JAD) [2] session was held to obtain the data to be stored in the RDBMS. That data definition has been expanded over the last 10 months to include more nuclear fuel cycle information. This has been a direct result of expansion of the original scope by the DOE and an examination of the Vital Issues results.

An examination of its geographical setting with respect to accident consequences lead naturally to events and entities which supply reactors and the consequences, waste and disposal, of reactor operation. The inclusion of information about the entire nuclear fuel cycle was a natural extension. The system will now include information about the fuel cycle from mining to disposal. The Vital Issues results had the effect of looking at information that was not strictly related to reactor operation but was a substitute for a PRA.

There are over 300 foreign commercial nuclear reactors world wide (excluding the United States). Time and resource constraints dictate that all information on all reactors cannot be included in the GIS. Ideally, the GIS would incorporate information on the most dangerous reactors first, information acquired by conducting a probabilistic risk assessment (PRA) of each of these 300 reactors. However, the cost and duration of performing PRAs makes this impractical. The Vital Issues process was used to identify criteria for choosing the most dangerous reactors (and so a near-term information focus for the FINIS) and to identify information needs on the part of the ultimate users of the FINIS.

One of the lessons learned while constructing the GIS is the flexibility of the data. As the customers involvement increased more peripheral information was added to the original data model. Giving considerable attention to the data model from the start has allowed us to add information about fossil fuel sites, support and utility services to fuel cycle sites as examples.

[2] The JAD technique was originally developed by IBM. JAD is a facilitated session that brings together the stakeholders, usually of a computer system, to rapidly produce a system requirements definition.

THE VITAL ISSUES PANELS

The Vital Issues (VI) process is a structured methodology developed by SNL for using groups of experts with diverse backgrounds to clearly define a problem (or dimensions of a problem) and then identify and rank issues of importance to the resolution of that problem. The process is explicitly designed to develop consensus among individuals with divergent perspectives on a problem of relevance to them and on various aspects of an approach to problem resolution. The Vital Issues process requires a high level of stakeholder involvement, ensuring that stakeholder perspectives are incorporated into the solution and predisposing acceptance of the programmatic approaches to problem resolution by those stakeholder communities. As a general rule, participants on each panel represent the perspectives of government (both executive and legislative); industry/private sector; academe; and special interest groups.

The Vital Issues process incorporates two primary approaches: a qualitative, or transactional method which takes a synthesis approach, and a quantitative or net benefit maximization method which performs some analysis activities. The transactional method uses facilitated dialogue to identify and define the topic of concern and constituent issues. Net benefit maximization uses quantitative methods to do tradeoffs among the members of a set of given alternatives, asking the panelists to rank the issues against identified criteria. Output from each panel is a report documenting discussion and graphic representations of the quantitative ranking of issues which also shows the amount of disagreement amongst the panelists as to the rankings (Glicken and Engi *in press*).

We used Vital Issues panels for this project in three areas: to define criteria to identify a dangerous reactor, to identify information needed to understand consequences of an accident, and to develop possible policy responses by the US. Due to the differing nature of the topic under discussion, each panel had a different constituency with representation of the four perspectives identified above.

The first panel in the series defined what was meant by an 'accident' in the context of this project, defining it as "a nuclear event that results in significant release of fission products from the core" (Glicken 1992). The panel then identified criteria that could be relatively quickly applied to foreign reactors to determine the likelihood that they would have an accident. Those criteria were plant design; plant condition; conduct of operations; regulatory oversight; support infrastructure; natural external events; and socio-political environment. The information categories needed to apply the criteria were also identified. Panelists were individuals with experience in identifying dangerous reactors and came from academe, the NRC (Nuclear Regulatory Commission), the private sector and the national laboratories.

The second panel used the definition of an accident synthesized by the first panel and addressed the spectrum of the consequences of an accident (Glicken 1993). The purpose of the panel was to identify topical areas and information categories that a policy maker would need to make a decision regarding response to that accident. Topical areas identified were economics and energy; health and environment; political and security issues; social issues; infrastructure issues; and cross-cutting needs. Information categories within each topical area were then ranked by panelists perception of their cost of acquisition and value to the decision maker. Panelists included representatives from academe, special interest groups, the private sector and the national laboratories.

The third panel will focus on possible US policy responses to an accident, given the likely consequences. Each of the three panels identified and ranked information categories that will be incorporated into the GIS and allowed the builders of the computer system access to individuals with a different perspective on the issue (than that of a program developer).

COMBINING THE TWO

Using only the GIS and the accompanying database or just the Vital Issues panel results to aid in rapid response to an accident or event does not exploit the synergism gained by the combination of the two approaches.

First, the fusion of these two data sets will help to identify missing information (information 'gaps') in the geographic or Vital Issues data sets that may be important to policy makers in the event of a nuclear accident. An example, the technical design of the original RDBMS failed to record threat as an important determinant for accident probability as indicated by the VI results.

Second, results of the paired comparisons rankings of accident probability characteristics from the Vital Issues panels plus the GIS and database permit the application of three other approaches; expert systems, statistical analysis, and simulation to provide ad hoc reactor characterization.

The expert systems approach would take the knowledge developed by the pairwise comparison results from the expert panels and incorporate them into a rule based system for determining various degrees of accident likelihood, consequence severity, and mitigation possibilities. The statistical approach would examine the data base for trends, clusters, and explanations of variation in the data. Statistical presentations also aid in data visualization, presenting the intrinsic structure of the data visually to aid analysts in decision making. The simulation approach would permit the linkage of dynamic simulation techniques describing accident scenarios in a simplified manner. This is a logical consequence of reactor characterization and testing of various accident scenarios by policy makers.

We will first use statistical and expert systems models to choose and group reactors; and second will use simulation to study accident consequences. Once a model is developed for one reactor it can be applied to all reactors, or any combination of them, in a matter of minutes.

Events are frequently occurring at reactors which may affect their risk characterization. The FINIS system can be queried at any time after the database is brought up to date with new information. Additionally, characterization criteria may change over time. With a stable database and GIS, different aspects of reactor characterization can be tested in a minimal amount of time.

SUMMARY AND CONCLUSIONS

The FINIS will be a valuable tool to US policy makers in the event of an incident at a foreign civil nuclear power reactor site as it will provide in a timely fashion and a usable format the information necessary to formulate an appropriate policy response. The expansion of the GIS with 'what if' and other capabilities also will allow OFI to provide warning of possible incidents, allowing policy and decision makers to deploy resources in a proactive rather than purely reactive fashion.

Perhaps as important as the information provided through queries of the completed system are the lessons learned and benefits gained through the process of building the FINIS itself. The perspective of an *ex post facto* analysis of a reactor site provided by the GIS allows us to incorporate a much broader universe of information into the FINIS than was originally envisioned. Information on the movement of materials and people in and out of the reactor site and the tracking of nuclear materials through the entire fuel cycle (both being geographically referenced sets of data) were recognized as important as the model building activity turned to consequences and responses. The Vital Issues panels provided a mechanism by which the computer model builder could understand priorities of the user communities and access the decision logic employed by such users.

The understanding to be gained by policy analysts and decision makers of the intricacies of the foreign nuclear environment using the capabilities of and the information contained in the FINIS can significantly contribute to effective policy and decision making.

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AN AUTOMATED SHELL FOR MANAGEMENT OF PARAMETRIC DISPERSION/DEPOSITION MODELING

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ABSTRACT

In 1993, the U.S. Army tasked Argonne National Laboratory to perform a study of chemical agent dispersion and deposition for the Chemical Stockpile Emergency Preparedness Program using an existing Army computer model. The study explored a wide range of situations in terms of six parameters: agent type, quantity released, liquid droplet size, release height, wind speed, and atmospheric stability. A number of discrete values of interest were chosen for each parameter resulting in a total of 18,144 possible different combinations of parameter values. Therefore, the need arose for a systematic method to assemble the large number of input streams for the model, filter out unrealistic combinations of parameter values, run the model, and extract the results of interest from the extensive model output.

To meet these needs, Argonne National Laboratory designed an automated shell for the computer model. The shell processed the inputs, ran the model, and reported the results of interest. By doing so, the shell compressed the time needed to perform the study and freed the researchers to focus on the evaluation and interpretation of the model predictions. The results of the study are still under review by the Army and other agencies; therefore, it would be premature to discuss the results in this paper. However, the design of the shell could be applied to other hazards for which multiple-parameter modeling is performed. This paper describes the design and operation of the shell as an example for other hazards and models.

INTRODUCTION

The potential threat to the public from the storage, transportation, and demilitarization of chemical agents and weapons by the U.S. Army has given rise to the Chemical Stockpile Emergency Preparedness Program (CSEPP). As part of CSEPP, the Army has worked with appropriate regulatory agencies and state and local organizations to assure that regulatory requirements are met and that adequate emergency response plans are in place to protect the public and the environment. The immediate concern following an accidental release of chemical agent to the environment is the exposure of people downwind of the release site to the airborne agent as the cloud of agent vapor or aerosol is transported by the wind. The potential extent of the vapor hazard has been examined in earlier studies. As the emergency planning process proceeded, it became apparent that more information was needed about the potential for deposition of chemical agent aerosol on the ground and other surfaces following an accidental release.

Initially, in order to obtain preliminary estimates of the possible extent of the agent deposition hazard, the Army employed its GAPCAP (Generation of Assessment Patterns for Clouds of Airborne Particles) model (1) to estimate the downwind extent of the agent deposition pattern. Only two release scenarios and three sets of atmospheric conditions were considered and the effects of other variations in the values of the model parameters were not investigated in detail. Because of the wide range of potential release scenarios that have been developed as part of CSEPP and because of the wide range of potential release conditions and atmospheric conditions that could occur, it was decided that an extensive study of the predictions of the GAPCAP model should be made. The study would examine model predictions for wide ranges of model parameter values that represent all credible release scenarios, release conditions, and meteorological conditions. In April of 1993, the Army tasked Argonne National Laboratory to perform such a study.

DISPERSION/DEPOSITION MODEL

The GAPCAP model assumes that the concentration profiles of the material being modeled can be represented by Gaussian shapes in the vertical, crosswind, and downwind directions. The size of these Gaussian profiles are specified by standard deviation parameters (usually referred to as sigmas) that increase as simple functions of transport distance in the downwind direction. In the present application, the chemical agent is assumed to be released as small liquid droplets that are transported by the wind and eventually deposited on the ground due to gravitational settling. The assumptions that all the agent is released as liquid droplets and that the droplets do not undergo evaporation during transport are considered to be conservative in that all agent originally released remains available for deposition.

Mixing and diffusion in the vertical direction cause the vertical dimension of the cloud to increase with time and, thus, with distance downwind. However, this growth will eventually be limited by the surface of the ground below the cloud and by an atmospheric inversion cap above the cloud. The inversion cap is often characterized by a relatively rapid increase in temperature with height and represents a stable layer that creates a limit to the potential upward growth of the cloud. The layer of air between the ground and the inversion cap is referred to as the mixing layer.

The GAPCAP model formulation assumes that the wind is constant in speed and direction, that the ground surface is flat and uniform, that vertical growth of the agent cloud is limited by an impenetrable atmospheric inversion cap at a fixed height, and that meteorological conditions are uniform within the mixing layer. These assumptions are also considered to be conservative in that wind meandering, additional turbulence due to surface roughness, unlimited vertical cloud growth, and changing atmospheric conditions all should tend to increase the dispersion of the chemical agent before it is deposited resulting in lower deposition levels as the agent would be spread over larger areas.

The input parameters of the GAPCAP computer model can be divided into two groups — physical parameters that describe the physical situation being modeled and control parameters that specify calculational and output options and govern the numerical computations. The physical input parameters are listed in Table 1. The source standard deviations ($\sigma_{x,o}$, $\sigma_{y,o}$, and $\sigma_{z,o}$) represent the initial size of the agent cloud at the point of release. The precise values of these parameters have little effect on the size of the cloud at downwind distances that are large with respect to the source size. The diffusion parameters (γ, α, and β) and the standard deviations at the reference distance ($\sigma_{x,R}$, $\sigma_{y,R}$, and $\sigma_{z,R}$) determine the rates of growth of the cloud as a function of downwind distance. (The reference distance is taken to be 100 meters in the GAPCAP model.) The values of these parameters are expected to be functions of the atmospheric conditions within the mixing layer. In the GAPCAP model, the wind speed within the mixing layer is assumed to be a simple function of height as described by the Frost Power Law (2) where wind speed at a specific height is determined by the wind speed at a reference height of two meters (u_R) and a power law exponent (λ).

TABLE 1 Input Parameters of the GAPCAP Model

Parameter	Description
ρ	Density of droplets
m	Mass of agent released
d	Diameter of droplets
H	Height of release
$\sigma_{x,o}$	Source standard deviation in downwind direction
$\sigma_{y,o}$	Source standard deviation in crosswind direction
$\sigma_{z,o}$	Source standard deviation in vertical direction
H_{ML}	Height of mixing layer
γ	Downwind diffusion parameter
α	Crosswind diffusion parameter
β	Vertical diffusion parameter
$\sigma_{x,R}$	Standard deviation in downwind direction at the reference distance
$\sigma_{y,R}$	Standard deviation in crosswind direction at the reference distance
$\sigma_{z,R}$	Standard deviation in vertical direction at the reference distance
K_m*	Generalized stability parameter (used in the calculation of the droplet settling velocity)
u_R	Wind speed at reference height
λ	Frost Power Law exponent

The GAPCAP model can be used to predict agent concentration, dosage (the cumulative sum of concentration over time), and deposition at points specified by a horizontal computational grid that extends in both the downwind and crosswind directions from the point of release. In addition to reporting the input parameter values and some intermediate computational results, the output of the computer code includes the model predictions over the computational grid in tabular form.

PARAMETRIC MODEL STUDY

A parametric study of the predictions of the GAPCAP model was carried out to quantify the potential extent of chemical agent deposition downwind of an accidental release from an Army storage depot. The values of the input parameters of the GAPCAP model were systematically varied over ranges judged to span the credible release scenarios and meteorological conditions associated with the eight chemical stockpile storage depots within the continental United States. The model was used to calculate the expected downwind distances to a series of deposition levels for the various combinations of input parameter values.

The first step in carrying out the study was to relate the model input parameters to the parameters of interest to the emergency planners and to establish appropriate ranges and increments for the parameter values. Some of the model parameters are essentially the same as the parameters used by the emergency planners to specify the release scenarios while others had to be related on the basis of the reported results of other studies.

The agents considered in the study were the blister agent HD and the nerve agent VX. The agent type determines the density of the droplets (parameter ρ in Table 1) needed as input to the GAPCAP model. A series of eight masses of released agent (parameter m) was selected for the study. The masses chosen were 100, 500, 1000, 5000, 10,000, 50,000, 100,000, and 500,000 lb. These values cover the range from a relatively small release, corresponding to the agent content of a few munitions, to a value comparable to the largest credible release identified in the Emergency Response Concept Plans for the eight storage depots.

The diameter of the liquid droplets (parameter d) that would be generated during an accidental release is difficult to estimate. In actuality, a continuous range of droplet sizes would probably be produced, with the details of the distribution dependent upon the release mechanism. Droplets could range in size from a diameter of 1 μm or less, which would behave essentially like a vapor, to large drops that would rapidly settle out and not leave the immediate vicinity of the release. Even though the GAPCAP model formulation has the capability to include a distribution of particle sizes within a single cloud, for the purposes of this parametric study, releases of uniform droplet size were considered to evaluate the effect of droplet size on the predicted deposition pattern. To cover the range of droplet sizes that probably could be transported beyond the depot boundaries, a series of six diameters from 1 to 500 μm (0.5 mm) was selected (1, 5, 10, 50, 100, and 500 μm).

The height of the release (parameter H) could range from near ground level to several hundred meters in the air, depending on the release scenario. For example, the accidental detonation of a munition during handling by a forklift would result in a release at essentially ground level; however, a release accompanied by a large fire could result in a large effective release height, because the agent might be carried upward due to the buoyancy generated by the heat of the fire. To cover a reasonably wide range of possibilities, a series of seven release heights was selected for the study. The release heights studied were 1 (corresponding to essentially a ground-level release), 50, 100, 200, 300, 500, and 700 m.

The dimensions of the effective source of the release, as specified by the source standard deviations in the model (parameters $\sigma_{x,o}$, $\sigma_{y,o}$, and $\sigma_{z,o}$), will depend on the quantity of agent involved and the manner in which the release is accomplished. However, the source dimensions have little effect on the behavior of the agent cloud as predicted by GAPCAP for downwind distances large with respect to the source size and the reference distance, x_R (100 m). In order to establish a consistent method of specifying $\sigma_{x,o}$, $\sigma_{y,o}$, and $\sigma_{z,o}$ for the parametric model study, the source dimensions contained in the database of another Army atmospheric dispersion model were examined. That model is the D2PC model (3) which has been used in previous analyses to estimate the downwind hazard from airborne chemical agents (see reference 4 for example). Based on the values of the source dimensions in the D2PC model database and on simple physical arguments, expressions for source standard deviations as a function of mass released (m), agent density (ρ), and effective release height (H) were developed for use in the parametric model study.

The remaining input parameters of the GAPCAP model except wind speed (parameters H_{ML}, γ, α, β, $\sigma_{x,R}$, $\sigma_{y,R}$, $\sigma_{z,R}$, $K_m{}^*$, and λ) are considered to be primarily functions of atmospheric conditions, particularly the atmospheric stability. Atmospheric stability is a measure of the relative amount of turbulence or mixing present in the atmosphere. Two of the primary causes of this turbulence are the uneven heating of the surface of the earth by the sun and the uneven flow of the wind over the surface of the earth due to its roughness. In a semiquantitative way, observed atmospheric stabilities are classified by meteorologists into categories. One such classification scheme, referred to as the Pasquill Stability Categories, consists of six classes designated A through F.

The rate at which air temperature changes with increasing height above the ground surface is often strongly correlated with stability. The most unstable category, with the greatest amount of turbulence, is A. Instability is often associated with a relatively large reduction in temperature and, thus, increase in density with height. Such conditions can usually exist only during the daytime, when solar radiation heats the ground surface and the air near the ground. The most stable category, with the least amount of turbulence and thus mixing, is F. This stability is often the result of an increase in air temperature with height and corresponds to a gravitationally stable condition of air density decreasing with height. These conditions usually only occur at nighttime, when solar radiation is not present to create and maintain unstable temperature and density profiles. High wind speeds tend to reduce the potential for temperature and density stratification and are usually associated with neutral stability conditions (categories C and D).

The U.S. Army D2PC model (3) also contains a database of atmospheric diffusion parameters as a function of atmospheric stability category. The values from that database were used to determine the values of the GAPCAP input parameters γ, α, β, $\sigma_{x,R}$, $\sigma_{y,R}$, $\sigma_{z,R}$, K_m*, and λ as a function of atmospheric stability category. A series of three atmospheric stability categories was selected for the parametric study of the predictions of the GAPCAP model. Stabilities B, D, and F were chosen to cover the possible range, yet limit the number of separate model calculations required to complete the study. Stability A was omitted because such extremely unstable conditions are rarely observed; the high levels of turbulence associated with this category should lead to rapid mixing and large dilutions, resulting in smaller downwind concentration and deposition levels than other stability categories.

Although the height of the mixing layer (parameter H_{ML}) depends strongly on atmospheric stability, it is also a function of such other factors as geographic location, topography, vegetation, and season. However, very stable atmospheric conditions tend to exist only beneath low inversion caps, whereas unstable conditions tend to occur when the inversion cap is relatively high. In order to allow the parametric model study to be carried out in a generic manner, without tying it to a specific release location and specific time of year, it was decided to associate a single value for the mixing layer height with each atmospheric stability category. The database associated with the D2PC model includes tables of median mixing-layer height as a function of stability category for each of four seasons at each of the eight storage depots. Average values across the eight depots and four seasons were evaluated for each stability category. These average mixing-layer heights were used in the parametric model study to assign values to the parameter H_{ML} as a function of atmospheric stability category.

A series of nine wind speeds (parameter u_R) was selected for the parametric study. The wind speeds chosen were 1, 2, 3, 5, 7, 10, 12, 15, and 20 m/s. The GAPCAP model formulation assumes the presence of a wind field that is uniform in speed and direction over both time and space. The lowest wind speed value of 1 m/s (about 2 mi/h) was selected because it is generally believed that this is approximately the lowest speed for which a relatively constant and uniform wind field can be maintained in nature (see, for example, reference 5). The upper limit on the wind speed of 20 m/s (about 45 mi/h) was selected because stronger winds are usually associated with storms or hurricanes, in which uniform wind speeds and directions are not maintained for long periods of time.

In summary, a parametric study of the GAPCAP model was devised that includes six parameters: agent type, mass of agent released, droplet diameter, effective release height, atmospheric stability, and wind speed. The parameters and parameter values used in the study are summarized in Table 2. On the basis of the number of values selected for each parameter (2 agent types, 8 release masses, 6 droplet diameters, 7 release heights, 3 atmospheric stability categories, and 9 wind speeds), there are 18,144 different combinations of parameter values possible.

TABLE 2 Parameters and Parameter Values for Model Study

Parameter	Values
Agent type	HD and VX
Mass released	100, 500, 1,000, 5,000, 10,000, 50,000, 100,000, and 500,000 lb
Droplet diameter	1, 5, 10, 50, 100, and 500 µm
Release height	1, 50, 100, 200, 300, 500, and 700 m
Atmospheric stability	Categories B, D, and F
Wind speed	1, 2, 3, 5, 7, 10, 12, 15, and 20 m/s

However, many of these combinations correspond to situations that are not physically realistic. Explicit restrictions can be applied to eliminate combinations that do not correspond to physical situations. As suggested in the D2PC model, restrictions limiting possible wind speeds for certain atmospheric stability conditions should be applied because very stable and very unstable conditions generally cannot persist unless the wind speed is sufficiently low. In addition, the release height must be within the mixing layer for the GAPCAP model to be valid. This condition adds the restriction that $H \leq H_{ML}$. These restrictions reduce the number of combinations of parameter values corresponding to physically realistic situations to 7,200.

AUTOMATED SHELL

In order to carry out the large number of computer runs required to complete the parametric study, an automated shell was designed and implemented to prepare the input for and process the output from the computer model. The actual GAPCAP computer code, which is FORTRAN, was used exactly as received from the Army with no modifications whatsoever. Using the original code eliminated the need to delve into the internal structure of the computer program and the risk of inadvertently affecting the computational results.

The automated shell was developed primarily as a "C-shell" script in a Sun/UNIX operating environment. C-shell is a command interpreter with a C-like language structure. Some specific routines used to access and manipulate the output files from GAPCAP were written in FORTRAN. Although GAPCAP can be run on a personal computer (PC), the Sun platform was selected primarily because of the excessive computation time that would be required on a PC to carry out the thousands of computer runs needed for the study.

Through a series of screen menus, the automated shell interactively allows the user to select from pre-established lists, values for the six parameters of the study (see Table 2) as well as agent deposition levels of interest. The user also has the option to enter additional values and select them for the study. Once the specific values of the parameters for the study are established, the shell systematically goes through all possible combinations of parameter values (18,144 cases in the present study). For each set of parameter values or case, the restrictions on physically realistic combinations of release height, wind speed, and atmospheric stability category are checked. If the particular case is not physically valid, an entry for that case in made directly in the appropriate output file with a flag character set to mark the case as physically invalid.

For the valid cases, the shell generates a GAPCAP input file containing values for the physical input parameters listed in Table 1 that are derived, through table look-up or simple computation, from the values of the six parameters of the study for that case. Values for most of the control parameters are constant for the entire study. However, allowance had to be made for the adjustment of a few of the control parameters during the running of each individual case. An initial value was established for each of these adjustable control parameters and a systematic scheme was developed for adjusting these control parameter values based on the output of the GAPCAP model run. The shell then repetitively runs the model until a satisfactory result is obtained or until no further adjustments in the values of the control parameters are appropriate. In either situation, an entry is made in the corresponding output file with the flag character set to mark the status of the case.

As mentioned earlier, the GAPCAP model generates a rather extensive output file. However, for the purposes of the present study, the only model results of immediate interest are the downwind distances to the points where the predicted deposition level drops below the deposition levels of interest to the emergency planners. Because of the symmetric nature of the GAPCAP dispersion model, this distance will always lie along the centerline of the predicted deposition pattern in the direction of travel of the wind. Once the shell has determined that a satisfactory model run has been completed, the GAPCAP output file is searched to identify, for each of the deposition levels of interest, the two grid points along the centerline of calculational grid where the predicted deposition levels bracket the deposition level of interest. Linear interpolation is then used to estimate the downwind extent associated with the deposition level. If the end of the computational grid occurs before the smallest deposition level of interest is reached, values of the appropriate control parameters of the GAPCAP model are adjusted and the model is run again.

After all the downwind distances corresponding to all the deposition levels of interest are found or when the limits of the model are reached, the results are written to an output file. In order to simplify further processing of the study results and to avoid any potential for misinterpretation of the individual results, each record in the output file is complete and self-contained. That is, each record contains the values of the six parameters used in the calculation, the specific deposition level of interest, the predicted distance to that deposition level, and a flag character that indicates the status of the GAPCAP computer run. Because 72,576 output records were generated for this study (18,144 combinations of parameter values times four deposition levels), a series of output files were created rather than producing one large file that would be difficult to manipulate.

When the model runs were complete, the information from the output files was loaded into a commercial database application on a personal computer. The database application provided a convenient way to sort and group the results; to examine means, extremes, trends, and other statistics representative of the results; and to produce formatted tables of results for inclusion in project reports.

APPLICATION TO OTHER HAZARDS

While this study focused on one man-made hazard, the concept of an automated shell could be applied to other hazards for which multiple-parameter modeling is performed. For example, consider the modeling of coastal flooding caused by hurricanes (6). Such modeling is a complex problem involving interactions among water, wind, atmospheric pressure, land, and earth rotation. Like the modeling of chemical agent dispersion, modeling of hurricane-induced flooding involves many parameters such as pressure at a given radial distance, peripheral pressure, pressure at maximum wind, a density coefficient, a Coriolis parameter, forward speed of the hurricane, and wind stress over the water surface. For purposes of emergency planning, the prediction of hurricane effects must account for many additional uncertainties such as the time, location, and direction of landfall. Also, like the present study, the results of hurricane and flood models are typically calculated for a large-scale spatial grid. Such a situation could readily lend itself to the use of an automated shell to manage a very large number of computer runs. The hurricane and flood hazard is but one example of a multiple-parameter modeling situation. Others can be readily conceived.

CONCLUSIONS

The results of the parametric study of the predictions of the GAPCAP model are still under review by the Army and other agencies; therefore, it would be premature to discuss the specifics of the results in this paper. However, based on the success of using an automated shell for the present study, the concept of using such a shell to conduct similar extensive parametric studies deserves consideration. Often emergency planners need to know the possible range of consequences of a class of accidents or natural disasters in a general geographic region rather than the detailed consequences of a specific event at a specific location. Computer models may exist that can be used to make predictions for specific conditions. However, it may be very difficult and time consuming to prepare input for numerous cases, run the model repetitively, and examine the results of each case. The use of an automated shell such as has been described in this paper can significantly simplify and speed-up this process.

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AN INTEGRATED APPROACH TO TECHNOLOGICAL RISK ANALYSIS AND PROTECTIVE ACTION DECISION MAKING

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ABSTRACT

Chemical warfare agents stored at eight military installations within the continental United States are scheduled to be destroyed through incineration over the next ten years. Extraordinary measures are being taken at all levels of government to ensure the safety of the public during the storage and disposal phases of the project. Key to protection of the public is development of protective action (PA) strategies, which must be determined prior to and implemented immediately following an accidental chemical release. Three sophisticated, interdependent models (that assess atmospheric dispersion of a chemical, traffic evacuation times, and dose reduction attributable to a particular PA) and a structured operational protocol have been provided to aid planning and management staff in this decision-making process. To equip individuals to utilize both the models and the protocol, a comprehensive instructional program has been developed that examines the risk–impact–response relationship and provides practice in use of the analytical tools. This instructional program may be able to serve as a prototype for use by other communities and chemical locations needing to analyze and plan for response to risks posed by the presence of hazardous substances.

INTRODUCTION

Within the United States there is ever-increasing recognition that with use of industrial chemicals in comes responsibility to protect the public from risks inherent in such use. Emphasis is being placed on developing and implementing "risk management plans" to reduce the likelihood and impact of accidental releases. Government agencies are issuing regulations and instituting programs to foster emergency preparedness within both the public and private sectors, and to encourage sharing of information between those responsible for chemical safety and accident prevention and those at risk. National and community-based organizations are assuming more vocal and proactive roles in ensuring all parties know of and effectively execute their respective obligations.

Prior to November 15, 1990, voluntary as well as limited, legally-imposed practices already were in place in many facilities that use hazardous materials. That day, however, saw enactment of amendments to the United States' Clean Air Act. Those amendments heralded the beginning of a more aggressive era in enforcement of a comprehensive suite of government requirements designed to further strengthen chemical safety

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management at operations that produce, handle, process or store certain hazardous substances. To fulfill their obligations under the law, qualifying chemical facilities must make projections about the risks they pose to nearby communities. They must undertake and widely share the results of a risk analysis yielding information that permits questions such as the following to be answered: *Where is an accident plume likely to travel? What risk does it pose to the health of exposed persons? Can people be evacuated before the plume reaches them? What is the optimum PA strategy to recommend given a particular set of circumstances?*

No longer is a narrow understanding of or limited focus on the problem acceptable. The new approach presents monumental challenges to all involved parties—those (often non-technical staff) who must perform and document the analyses and subsequently undergo intensive and extensive scrutiny, those who must develop and document response plans and subsequently ensure community members they will be protected, and those who are identified as being at risk and subsequently must evaluate the adequacy of information they receive about risks and planned PAs.

Although 1990 brought a heightened federal emphasis on protecting the public from chemical accidents, Congress years earlier had made its position quite clear on the matter. In 1985 it directed that *maximum protection* be provided the civilian population living adjacent to military locations where chemical warfare agents were stored and destined for destruction (US Army, 1987). This gave rise to the Chemical Stockpile Emergency Preparedness Program (CSEPP), a tri-partite undertaking of the US Army, Federal Emergency Management Agency and ten states.

Drawing upon the experiences gained in preparing jurisdictions within these ten states to conduct such critical analyses, this paper addresses a multi-faceted program focused on the risk–impact–response relationship. In CSEPP, state and local staff (most without extensive scientific orientation) are expected to utilize three sophisticated models and a highly structured "hazard vulnerability analysis" protocol to develop PA strategies to protect people during accidental release of chemical warfare agents stored in eight military installations within the continental United States. While the CSEPP, the chemical agents, the models and the protocol combine to form a situation unique to limited number of states and counties, their existence has served as the impetus for development of a comprehensive planning program and accompanying interactive, multimedia training package that may serve as a prototype for use by other communities and chemical facilities.

COURSE STRUCTURE

The goal of the Technical Planning and Evaluation (TPE) training course is to provide a framework that can be used in analyzing chemical risks, developing PA strategies appropriate for particular circumstances, and for evaluating, modifying and updating existing local emergency management plans [Copenhaver et. al, 1994 (Draft)]. In short, it teaches a PA decision-making process appropriate for the CSEPP.

Designed for both planners and managers, TPE addresses general information on protective action planning and computer forecasting models; analysis of planning standards providing the foundation for the planning process; interactive, computerized tutorials on the different models and planning concepts; and skills development to provide participants an opportunity to use the integrated models in analyzing sample scenarios. The course consists of six major modules: Introduction and Key Concepts, Implementing the Standards, Oak Ridge Evacuation Modeling System (OREMS), D2PC (an atmospheric dispersion model developed by the US Army), Protective Action Dose Reduction Estimator (PADRE), and Evaluation. Each module contains two units: a computer-assisted instructional (CAI) unit covering the general concepts and principles; and a workbook-based example that is analyzed utilizing the models themselves, forms developed to guide the process, and job aids that provide additional instruction or data needed to run the models.

Computer-assisted instruction was chosen as the delivery vehicle for two main reasons: the CAI offers opportunity to display concepts visually—cutting through many barriers to learning; it also aids in teaching general use of computers, which is extremely valuable when teaching planners to use computer tools for the first time. The course examines the need for and logic underlying a family of forms, included in an extensive workbook, which have been designed to structure, guide and document the analytical and decision-making process. Data forms are an important part of the process; they provide a structure for the planning effort. Without their use, important data may be lost and replication of decisions and outcomes may be impossible. These forms may, in time, be automated to lessen the burden on the planning staff [Clevenger, et. al, 1994 (Draft)].

PROTECTIVE ACTION DECISION-MAKING PROCESS

The presence of chemical agents in a community presents an identifiable hazard. This hazard can be measured in terms of an individual's risk of exposure to agent and any subsequent dosage. Various tools (i.e., models), have been developed to examine the interaction of the chemical agent characteristics, environmental conditions and social configurations, and also to help evaluate the effectiveness of various PAs in terms of dosage reduction. The models used as planning tools in TPE were developed within the framework of the PA standards for CSEPP. The CSEPP Planning Guidance and Standards also function as a framework for stating the planning problems, utilizing available tools to suggest solutions to these problems, and then systematically producing plans to address the potential problems. The standards raise three questions intended to guide planners while developing emergency plans:

- What is the critical information needed to make a PA decision?
- How can a planner get this information into an emergency PA plan?
- What features of a plan can allow for speedy decisions to be made during the emergency response phase?

Different PAs are appropriate for different population segments under different emergency conditions. There is not enough time during an emergency to analyze the situation to decide what PAs are appropriate. To deal with this time restriction, the CSEPP PA Decision-Making Standards recommend that the planner/decision maker perform all substantive decision-making tasks during the planning phase. If this is done, at the time of emergency the appropriate sets of predetermined decisions can simply be implemented based on the conditions that apply at that time. The components of a PA Strategy include: what accidents can happen; what meteorological conditions could transport a chemical agent into the communities; and what population needs to be protected, where it is located, and who comprises the population (general population, school children, elderly, handicapped, and institutional residents).

MODELS USEFUL IN PROTECTIVE ACTION DECISION MAKING

OREMS is a "stand-alone" software system for traffic operations analyses and evacuation time estimate studies associated with population evacuations. The system consists of a set of related programs which operate under a "common shell". This common shell allows the user to create input data files interactively and graphically, to simulate traffic operations during evacuations, and to analyze simulation results interactively and graphically (Rathi, et. al, 1994).

D2PC is a computer program that estimates the downwind hazard from the release of a toxic chemical by simulating the behavior of airborne releases of a chemical agent. Hazard assessment is made in terms of the accumulated dosage or peak concentrations of agent resulting from an instantaneous, continuous, or other type of chemical release. D2PC is an air dispersion model that assumes that when agent is released and begins to travel downwind, it is most concentrated in the middle of the plume and less concentrated further away from the middle of the plume (Whitacre et. al, 1987).

PADRE is a software package that compares the total dosage of chemical agent a person would receive, given a specific emergency response and PA, to the dosage a person would receive if no PA was taken. It evaluates PAs: evacuation, shelter-in-place, and supplemental a option for respiratory protection [Sorensen et. al, 1994 (Draft)].

It is important to stress that models can only aid the planner in developing a good plan. They do not replace sound judgment and planning experience. Models provide useful approximations of real events using a limited amount of information. Models are developed around a given set of assumptions of which the user should be aware. One of the most important steps in using models is collecting the data. Models can help us process information so that we obtain much more from a given set of data than we would without using models. Models help clarify relationships among concepts, and help users see complex interactions more clearly. The planner must be aware of the limits and integrity of this information and the effect that the data limits can have on each of the models. There tends to be an overemphasis by users on the exactness and rigor of the model that is not justified (Kaplan, 1964).

PLANNING PROCESS: STEPS IN DEVELOPING A PROTECTIVE ACTION STRATEGY PLAN

TPE introduces a ten-step process to follow in developing a PA Strategy Plan containing PA strategies and an emergency decision process. There are two basic PAs available for the public in a chemical emergency: evacuation and shelter. However, these options may be used in conjunction with supplemental protective measures.

Step 1: Developing Initial Accident Categories. In this initial step planners choose a set of beginning values for critical characteristics needed to develop groups of accidents (categories). These characteristics include type and amount of agent, duration of release, windspeed, and stability class. A category of accidents, when evaluated by these planning tools, should include the range of accidents likely to result in the same PA recommendation.

Step 2: Develop Meteorological Categories. Meteorological conditions, which have a great impact on downwind distances at which no deaths would be expected, are important factors in defining accident categories. The downwind distance values produced by a specific set of meteorological conditions can be used to create ranges of meteorological values to be used in developing PA strategies.

Step 3: Use D2PC to Determine Safe Distances for Each Accident. This step uses the model D2PC to calculate the downwind distance to safety. This distance is later used in determining how far people must travel to reach a safe area and, given the speed of travel, how much time it will take for them to be protected.

Step 4: Characterize Subzones. When developing planning subzones, the first subzone chosen for analysis should be the subzone with an at-risk population that is nearest to a potential chemical agent release. It is then appropriate to move to subzones that have the next nearest at-risk population until you have planned for your entire location. To complete this step, planners must develop planning assumptions for each planning subzone, identify population and population subgroups, and develop PADRE assumptions for each subgroup/PA combination. It is in developing assumptions for use in PADRE that information from D2PC and OREMS is integrated into this ten-step process.

Step 5: Run PADRE. In this step, the PADRE model is used to calculate the expected dose and the relative number of people affected if no PA is taken; the expected dose and relative number of people who receive a reduced dose if specified PAs are taken; and the relative number of people who, due to implementation of the PA, receive no dose or are protected when the plume arrives. PADRE is the central model in the development of PA strategies.

Step 6: Use PADRE Results to Complete a Protective Action Table (Matrix) for the Planning Subzone. In this step, planners compare PADRE output to values collected on health effects of the chemical agents to see if the reported dose is a significant health hazard in order to determine which of the tested PAs provides the greatest reduction in dose.

Step 7: Reduce Matrix to Protective Action Checklist for Each Unique Protective Action Strategy for Subzone. The purpose of this step is to group information from the previously generated data into similar PA strategies and document changes in PA recommendations. This step helps to reduce the quantity of information that planners must consider by consolidating model runs with similar PA strategies. This step helps the user determine the lower and upper boundaries of agent amount, duration of release, windspeed, and atmospheric stability class associated with each of the PA recommendations. This determination is based on the PADRE output and comparisons of those values with selected health data values.

Step 8: Prepare Protective Action Summary for Subzone. This step involves entering the data from the *PA Checklists* into a summary table which lists the different PA strategies for the subzone and provides them with unique identifiers. When the *PA Matrix* has been simplified by determining the lower and upper boundaries of agent amount, duration of release, windspeed, and stability class which, in turn, determined the specific PA recommendation, each unique PA Strategy identified by the analysis is entered into a *PA Strategies Summary Table*. This collection of PA recommendations becomes the PA Strategies for the chemical agent storage location.

Step 9: Prepare Decision Process Form for Subzone. This step uses the unique recommendations from the *PA Checklist* and the *Summary of PA Strategies* to document the links between the accident conditions, meteorological characteristics and the recommended PAs. That is, it lists the set on conditions that would lead decision makers to recommend each PA.

Step 10: Prepare Decision Matrix. Once analysis for all planning subzones is completed, it is then possible to create an overall decision table for all subzones (Fig. 1). Step 10 combines the information from different subzones and establishes the links between the accident conditions, meteorological characteristics and the recommended PA strategies. It also links the

Fig. 1 Decision Matrix

Decision Process for Planning Subzones in an Accident Involving Agent *VX* A7 **Form J**

If Amount of Release is:	AND Duration is:	AND Windspeed is:	AND Stab. Class is:	And WD is:	THEN Implement: H1 for subzone	strategy
40 lbs	*20 min*	*< 4 mps*	*A*	*> 40° and <120°*	*A*	*PA1*
40 lbs	*20 min*	*> or equal 4 mps*	*A*	*> 40° and <120°*	*A*	*PA2*

The last two columns of this table are created by overlaying a directional grid on a planning map and determining whether or not a subzone is affected by a given wind direction. Planners may decide to recommend that all subzones within 90º of a wind direction are considered to be in the path of a plume and should implement the predetermined protective action strategy for the given wind conditions. The Strategy Column is the information contained in Form H for the different planning subzones.

recommendations back to the planning subzones by indicating wind direction. In the event of a chemical release, this matrix can be consulted quickly to determine what pre-planned PA strategy is to be immediately implemented, given the conditions of the release.

ROLE OF TRAINING IN TECHNOLOGY TRANSFER AND POLICY IMPLEMENTATION

The challenges inherent in transferring technology (e.g., analytical tools such as the models addressing atmospheric dispersion of accidental releases, forecasting dose reduction from PAs, and forecasting evacuation times based on local conditions) from the hands of experts to lay persons are extensive. Training can play a critical role in facilitating that transfer. When complex technologies such as computer models are to be used to perform tasks and reach policy decisions, training personnel to use those technologies effectively and consistently can make their use routine for decision making by planners and management personnel alike.

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NEW TOOLS FOR EMERGENCY RESPONSE AND MANAGEMENT: ADVANCED R&D THROUGH TECHNOLOGY TRANSFER FROM OUR FEDERAL LABORATORIES.

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ABSTRACT

Present-day emergency management continues to try to advance the state-of-the-art in using new tools and methods to plan for and control emergencies. Yet, to this day, most of the work of locating, extricating, and treating victims of these emergencies is "pick and shovel" technology. This nation needs to take the lead in developing the new technologies and systems needed to enhance the survivability of victims of disasters.

The federal laboratories (especially the national laboratories involved in weapons R&D) and federal agencies in general are presently undergoing major changes in their missions, funding, and in their ways of doing business. One issue that is emerging as a common denominator in the survival equation for each of the federal laboratories is that of technology transfer. Technology transfer is seen as a major need for bringing technology out of the laboratories to the civilian sector for development into either civilian use or dual-use (civilian and military) products.

THE "HOPEFUL" SCENARIO

It's midmorning in greater Megalopolis, and the downtown area is "normal," with people living, working, or just trying to survive in the big city. The sidewalks are small rivers of humanity, all of which seem to be fighting their way upstream to their destinations. Vehicles clog the streets and the homeless line the sidewalks. These are the everyday obstructions to "living the good life" in the big city that its denizens have come to cope with.

It's also the not-so-distant future that we've all predicted, feared, and avoided all those years. However, the present and enlightened administration elected by a country demanding change and responsibility has responded with a comprehensive disaster mitigation plan that has provided a nationwide emergency management organization based on preparedness, advanced technology, local responsibility, and governmental agency support. Although not yet perfect, the new system has developed a new awareness in our country so that citizens are preparing themselves to survive in a disaster.

Deep in the earth on a major fault, rock slips past rock after building up huge stresses over the years. P and S waves radiate from the huge section of fault, aiming directly at Megalopolis. The new, statewide network of seismic monitors detects the movements and transmits the signals to the State Center for Disaster Mitigation (CDM) by satellite. the CDM's massively parallel computer system quickly analyzes the data, using a worldwide network to access other data, expert systems, artificial intelligence, neural networks, and calculations from other computers in various government, university, and private organizations. The CDM's computers quickly analyze the signals, deduce the magnitude and location of the seismic activity, and predict the possible results to populated areas in the area. Within seconds, the computers have been able to tell the scientists in the CDM that a major earthquake is beginning to happen, and that the seismic waves will soon start propagating their destructive powers. Megalopolis is threatened!

Seeing the warning and remembering the predictions of major seismic activity from the previous days, the CDM Director activates the state's Disaster Early Warning System. All media immediately begin to broadcast a warning, and the small, lipstick-sized Personal Disaster Notifier/Locator (PDN/L) that all residents of Megalopolis carry emits a shrill siren sound. Because residents were already aware that a major earthquake was imminent (thanks to the CDM's new earthquake predictive capabilities), they are now able to seek preplanned shelters. As workers exit their office building, their PDN/L is interrogated by the building management system, keeping track of who is still in the building. The building management system's database is queried to determine where each person is most likely to be located in the building.

Only a couple of minutes elapse from the initial jolt at the epicenter to the arrival of the quake at Megalopolis, but those couple of minutes have allowed thousands of people to seek shelter, emergency units to be dispatched to their primary staging areas, and all emergency services to alert their staffs to report to their disaster duty stations to prepare for the first victims or to take shelter themselves.

Although new, enlightened, tougher, and better enforced building codes have made buildings and homes more resistant to the forces of the earthquake, this major quake inflicts heavy damage and many victims are killed, injured, trapped, or made homeless. Now, all the city is delayed on its "way to the good life!"

Within minutes after the quake has subsided, the first emergency responders are dispatched from their staging areas to begin the work of locating, extricating, and treating the victims. Overhead, the satellite starts mapping the disaster area, sending it down to the CDM where the visual and infrared data starts putting together a picture of the situation. At airports outside the disaster area, the Air Force dispatches reconnaissance planes to fly over the area to use the latest remote sensing technology to provide more detailed disaster assessment information. In minutes, new maps are generated and then compared with existing area maps, and the extent and magnitude of the damage become shockingly apparent. The new maps are immediately digitized and transmitted on the new Disaster Communications Network, accessible by all disaster agencies, and completely compatible with all communication systems in the country. Copies of the maps and an initial damage assessment is transmitted to the state's Emergency Operations Center (EOC), as well as to the Federal Emergency Management Agency (FEMA). The State Incident Commander contacts the governor of the state and suggests that the governor request a declaration of disaster from the President.

As preparations are made to bring in outside help, the local emergency response units are already at work. Fully equipped disaster vehicles bring in specialized equipment. More equipment is issued from strategically located caches, both within and around the disaster area.

First responders are in shock themselves, but they rally to begin locating and treating those who are trapped under collapsed structures or in vehicles. First responders and citizen volunteers, some of whom are walking wounded themselves, begin the heartbreaking chore of digging out.

The initial mass confusion is lessened as volunteers remember the training received at their workplaces, and they form into rescue and first aid teams, using both their personal survival equipment and the equipment they can salvage from the caches their companies have stored for this very purpose. In the next few hours, many victims owe their very lives to these initial volunteers and first responder units.

Meanwhile, the state government has responded to this major disaster. Most Megalopolis resources are already committed, so mutual aid has been requested, and is already pouring into the EOC-assigned staging areas. Modular, easily transportable units arrive by ground and air to provide heavy rescue equipment, field trauma treatment centers, and command, communications, control, and information (C^3I) capabilities. Logistics units set up portable power generators, initial communications lines, portable shelters, and sanitary facilities. Fast-moving recon/rescue teams go to work triaging buildings and victims, followed by heavy rescue and medical units. Small, all-terrain vehicles allow personnel and equipment to move into areas congested with debris. Computer-based, completely interoperable communication systems talk to all on-scene resources and surrounding jurisdictions. The National Guard is mobilized, providing personnel and equipment. The Guard units have received training in Urban Search and Rescue (US&R) and are assigned immediately to augment the local rescue efforts.

Local, state, and federal agencies have responded with specially equipped US&R units. Now, field units are operating victim locator devices that are based on seismic, acoustic, infrared, visual, and ground-penetrating radar technologies that can both locate the victim and determine whether the victim is still alive. Rescuers use high speed tools with special coatings to cut through concrete and rebar quickly. Foams and expandable grouts provide shoring and help move pieces of debris. Small hand-held sensors quickly determine the presence or absence of dangerous gases, hazardous materials, or live electrical circuits. Dust is sucked away by portable ventilation systems and clean air is directed into the work area. Large concrete pieces such as highway structures are quickly penetrated, cut, and moved, allowing fiber optic viewing devices with infrared capability to be inserted to help locate victims and assess damage.

As victims are found, a portable diagnostics unit uses near-infrared spectroscopy to determine the patient's condition. Quick setting foam is used to provide form-fitting immobilization and splinting, and dressings based on artificial skin technology are applied. If necessary, a laser scalpel can provide quick field amputations, and a computer controlled fluid infusion device provides fluid replacement and monitors the victim's condition as extrication and transportation is accomplished. A hypothermia vest is used on patients whose bodily functions have been affected by exposure to cold, and burn victims are treated with the new artificial skin dressings. As each victim is removed, a 3-D bar code tag is generated on a portable computer that carries complete information on the status and treatment of the victim. This tag follows the patient completely through the rescue and medical system, and is updated at each stage of treatment. This information can be read at the treatment center and transmitted to the operations center to be part of the incident records.

Within a few hours, FEMA US&R Task Force Teams and the National Disaster Medical Assistance Teams (DMAT) begin to arrive, and volunteer support agencies begin to set up to help the victims. Mobile advanced life support units are deployed in the area, and field hospitals are set up by the DMAT units. The military is now providing a continuous supply effort, bringing in rescue, medical, and logistic supplies from nearby supply caches managed by FEMA. The disaster operations now begin to convert from rescue and treatment to shelter and feeding of the survivors and the ultimate rebuilding of the disaster area.

The road to the "good life" is now lined by thousands of caring people providing helping hands to the survivors—in the best American tradition! Many people owe their lives to those who risked all to help, and to the new equipment and methods that allowed quick rescue and effective treatment of the victims.

THE "REAL WORLD"

The "hopeful scenario" of the preceding section is not now possible. In fact, present abilities to respond to and mitigate the effects of the "Big One" are very reactive, not proactive, and—in some cases—do not exist. Local response capabilities will be immediately overwhelmed in most cases in any moderate-to-large disaster, and the tools and methods available to rescue and treat the victims is both fairly low-technology and in short supply. Above all, there does not now exist a community or personal awareness, concern, or state of preparation that allows individuals and communities to both prepare and respond adequately to a major disaster.

Even given a "new citizen mindset" that would provide a better preparedness, it is commonly acknowledged in the emergency management and disaster response community that new and improved tools and techniques are badly needed if we are to provide an adequate response to the large disasters of the future. Robert P. Fletcher, Jr., Chief of the Federal Response Division of the Federal Emergency Management Agency, states that "...much additional research into equipment design and considerable development of equipment capabilities for use in both urban and heavy rescue environments are badly needed."[1] New technology that can be applied to all types of search and rescue, field and hospital treatment of the victims, and command operations will greatly help to mitigate the effects of the disasters we are sure to face soon.

The bottom line of the "US&R problem" is that our nation needs to take the lead in researching the technologies needed to enhance the survivability of victims of disasters. This will require several courses of action, such as

- establishing a viable national system of US&R, supported by Congress and responsible federal agencies,
- maintaining trained heavy rescue US&R teams, available on short notice,
- educating the public, so that they will be better able to prepare and respond to a disaster affecting their area, and
- providing better equipment and methods to rescuers, based on new or advanced technologies to improve their performance and uselfullness.

As discussed in a previous paper,[2] it is in this latter area that the federal laboratories can best contribute ideas and resources. The pool of talent at our federal laboratories represents a deep and as-yet untouched treasure of new technology that has great promise in improving the tools and methods required for US&R. There are a great number of technologies that have an application for US&R, either to improve equipment or methods.

Proposals have been presented to several federal agencies to try to interest them in promoting advanced technology for the US&R and disaster mitigation and response areas. The subject of these proposals, the Disaster Mitigation and Rescue Technologies Program (DM&RTP) provides many program development opportunities and new revenue potentials. The program is based on finding technology transfer opportunities for Los Alamos National Laboratory (LANL) and other federal laboratories. By working with LANL's Industrial Partnership Center and other laboratories' technical transfer offices, Cooperative Research and Development Agreements (CRADAs) will be developed for new products based on one or more technologies available at each laboratory.

This program has been proposed and pursued since 1991, but has yet to be accepted by any federal agency willing to provide funding. One reason for this is that the majority of programs presently offered by the federal agencies to promote technology transfer require that the federal laboratory team up with an industrial partner as part of the initial agreement. The objective of the DM&RTP is to find those industrial partners, so there is an immediate problem presented by the lack of an industrial partner. Although the program is still being actively pursued in its original form, it is also being approached by trying to locate a company that would be interested in some more specific part of the project. The objective of this approach would be to match a specific new technology with a new system or product that could be developed for the emergency market.

The Disaster Mitigation & Rescue Technologies Program offers some very attractive benefits to both the federal laboratories and industry. Some of these are as follows:

- Develop stronger ties between the laboratories and the Department of Defense (DOD) to support defense conversion initiatives.
- Help meet a major national need to provide a better capability for DOD, FEMA, and other agencies tasked under the Federal Response Plan to meet their responsibilities to provide a national US&R Emergency Support Function.
- Develop laboratory-wide outreach activities that will focus on laboratory spin-off technologies.
- Establish start-up companies using the laboratory technologies.
- Help obtain funding for new industrial partnership programs.
- Increase applied civilian R&D.
- Enhance interactions with industry in civilian and dual-use technologies.
- Explore innovative ways to expedite the pickup of technology for commercial applications.
- Allow the Lab to empower its employees to help shape the directions of and strengthen the Lab through their actions and regain throughout the Lab a sense of citizenship, responsibility, and accomplishment.
- Help the Lab and other federal agencies convince the nation that its investment in people and facilities for defense is a major asset for finding solutions to other evolving, important problems facing the nation.

It is the author's most sincere hope that the new administrations in the Department of Energy, the Department of Defense, and the Federal Emergency Management Agency will be more interested in meeting this important national need for better systems and technology. It is also intended to bring the program to the attention of the Vice President with the help of the LANL management. Proposals are to be presented to try to bring the program to reality, along with a continual effort to try to find industrial partners to develop technologies into useful products.

SUMMARY

The Disaster Mitigation & Rescue Technologies Program provides the best possibilities of improving the equipment and methods required for US&R. Advanced equipment and methods are required to improve the chances of getting to victims and removing them faster, treating them better, and minimizing the damage caused by catastrophic earthquakes. If we continue to rely on the "pick and shovel" technology we now use, the casualty and damage figures will continue to climb. The resources of our federal laboratories provide the maximum potential for improving the protection of the health and welfare of citizens vulnerable to catastrophic disaster.

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Robert J. Crowley is a Staff Member in the Reactor Design & Analysis Group at Los Alamos National Laboratory. His background is in electrical and electronics engineering, with 28 years of professional experience in instrumentation and control, as well as a 35-year involvement in search and rescue, fire, medical, and other similar activities. At the present, he is working on developing sensors and instrumentation for environmental restoration projects at LANL, as well as developing the Disaster Mitigation & Rescue Technologies Program in the federal laboratories.

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EARTHQUAKES

EXPERT TSUNAMI DATABASE FOR THE PACIFIC REGION

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Abstract
The objective of the proposed project is the development of the Expert Tsunami Database (ETDB) on regional and Pacific-wide basis for further application in tsunami warning, risk assessment and mitigation. The ETDB is intended to be a comprehensive source of observational data on historical tsunamis in this region along with some basic additional and reference information related to the tsunami problem and to provide an enhanced environment for IBM PCs and compatibles for retrieval, visualization and processing of data.

1. Introduction

The compilation of historical data on tsunami occurrence and coastal manifestation is an important part of investigation of tsunami problem for any tsunamigenic region of the Pacific and elsewhere. Traditionally, historical data have been compiled and published in the form of tsunami catalogs as for the whole Pacific as for its particular regions. However, the data in the paper catalogs become obsolete rather quickly. Besides, they have the fixed predetermined format that makes their retrieval and handling rather complicated and time consuming process. The modern information technology demands the organization of data in the form of databases, where data are in the active form and their handling can be interactively made in the fast and efficient manner.

Recent achievements in the development of PC-based DBMS software along with declining prices of personal computers provide an excellent opportunity to bring all observational tsunami data to a desk of the researcher who wish to have all available information at his hands. It is highly desirable to make all regional and Pacific-wide tsunami catalogs available to individual researches and provide them with a specialized PC-based software which can be easily used to manipulate with this type of data. Direct access to historical tsunami databases in a standardized format along with basic mathematical models of tsunami behaviour and efficient processing tools will open new possibilities for investigations related to many aspects of the tsunami problem.

Database technology has been significantly developed over last two decades for all kinds of computers including mainframe, mini and personal computers. However, this development was mainly in response to commercial data processing needs, which are characterized by large, record-oriented, fairly homogeneous data sets mostly retrieved by relatively simple (point, interval and range) queries.

But today, database research and practice are increasingly concerned with other application, such as management of spacial data that stretch the conventional DB technology to its limit and beyond. One of the main feature of these data is that are embedded in space and are typically accessed through their position in space.

In response of these needs, the new class of the supporting software - Geographical Information Systems (GISs) has been developed and since the beginning of 80's became an important area for software development.

In the past, the GISs have concentrated mostly on retrieval and display problems, but now they are beginning to develop the analytical and modeling tools. Today some of GISs can provide a very sophisticated and enhanced environment for spacial data handling and processing. The ability of GISs to handle and analyse spatially referenced data may be seen as a major characteristic which distinguishes GIS from information systems developed to serve the needs of business data processing as well as from CAD or map production systems.

However, as many of standardized multipurpose systems, GISs are turned out to be not very flexible and cost effective for a number of specific, particular applications like geophysical data compilation, storage and processing. Their price and computer requirements are usually much higher than the standard DBMS software. Besides, in the most of existing GISs, the compiled data are related to socio-economic phenomena and are often organized in an administrative hierarchy, so that all further data queries should strictly follow this hierarchy.

That is why the development of the inexpensive PC-based software for the handling of geophysical and, in particular, earthquake and tsunami data is still the matter of interest.

2. ETDB concept

As a result of a feasibility study, a concept of the Expert Tsunami Data Base (ETDB) was developed at the Tsunami Research Group of the Novosibirsk Computing Center, Russian Academy of Sciences. The ETDB contains in the digital form all available earthquake and tsunami information for a particular region (source parameters, observed heights, original historical descriptions, etc.) as well as basic reference information on regional seismic and mareograph networks, regional geography, geology and tectonics. Additionally, it includes some blocks for tsunami modeling (e.g. calculation of travel time charts) and some standardized built-in tools for data processing and plotting. The specially developed graphic shell provides the possibility to manipulate maps, models and data in the convenient and efficient manner.

In elaborating the ETDB we are to meet the following basic requirements:

(1) system should have a module structure allowing flexibility and adjustment to particular application as well as to be an open system providing the potential of growth to keep abreast of research advancement;

(2) it should have built-in computer mapping subsystem providing the ability to display the data on actual geographical bases;

(3) system should have built-in tools for some standardized data processing and analysis;

(4) system should have a friendly user's interface based on menu -driven approach.

We proposed to build the ETDB on the basis of Hypertext conception which allows the integration within one software system of all kinds of data: numerals, text, graphics, source codes (e.g. mathematical models), even audio and video information. The ultimate goal of the ETDB Project is to develop the comprehensive database on tsunami and related geophysical phenomena, which contains the complete set of original, uninterpreted information available to anyone who wishes to revise estimates, to make his own interpretation, to raise questions or to propose improvements. The final product could be used not only as a comprehensive tsunami database, but also as a convenient electronic textbook and reference book on the tsunami topic as well as a computer-aided device for investigation of different aspects of the tsunami problem.

According to our conception the Expert Tsunami Database should exist in two forms which can be called conventionally as the parents' form and the user's form. The database in its parents' form should exist at a regional warning center or specialized data center on some dedicated hardware and be provided with continuing qualified maintenance, that is, to have the database administrator who is authorized and responsible for routine updating, editing and refinement of data.

In its user's form, the ETDB exists as an automated tsunami catalog embedded inside a specialized graphic shell that is a user's interface and provides possibilities for fast and convenient retrieval, visualization and handling of data. In this relation the user's database represents an electronic analog of conventional tsunami catalogs, however considerably surpasses them in its efficiency and convenience. The user's database is also provided with some tools for data editing and further data compiling that makes possible to use it as a basement for development of the personal database containing all the meaningful information related to the needs of the individual researcher.

The potential application of the ETDB can be threefold:

(1) facilitating the decision-making process at the regional Tsunami Warning Centers;

(2) in-depth education and orientation of officials, public demonstrations and pre-event emergency planning;

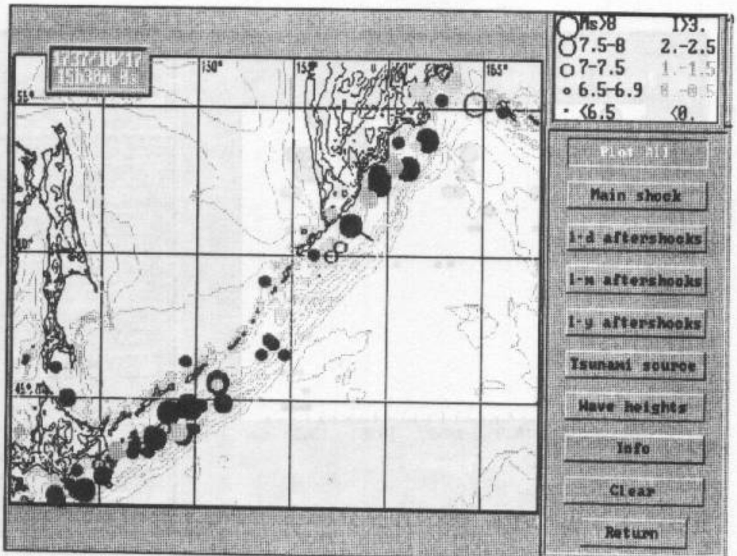

Fig.1. Map of epicenters tsunamigenic earthquakes occurred during 1737-1990 within the Kuril-Kamchatka region. The size of circles represents the event magnitude, the density of black tone - tsunami intensity.

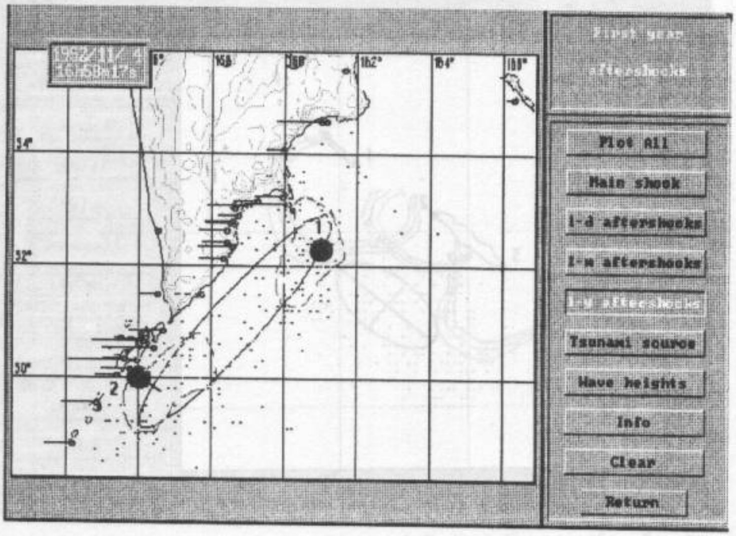

Fig.2. Visualization of tsunami data for the selected event of November 4, 1952. The solid ellipse shows the estimated position of the tsunami source. Black points represent the first year aftershocks. Sections of black lines show the run-up heights observed during this tsunami.

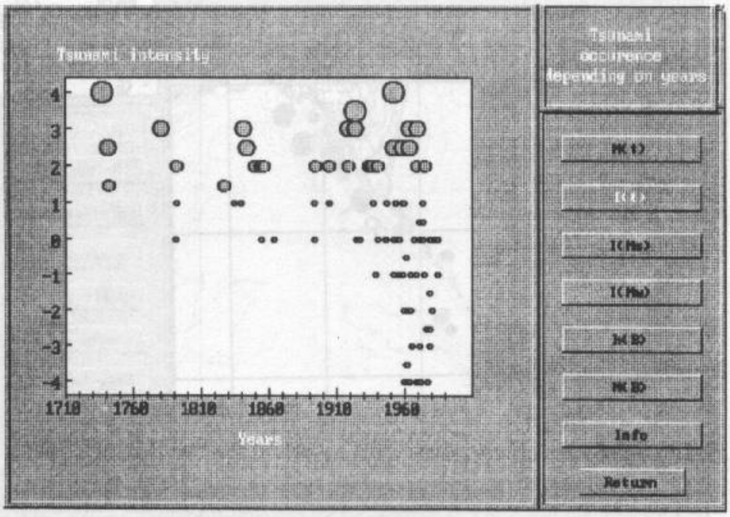

Fig.3. An example of application of the built-in analyzing software - tsunami occurrence depending on a year. The size of circles is proportional to the tsunami intensity.

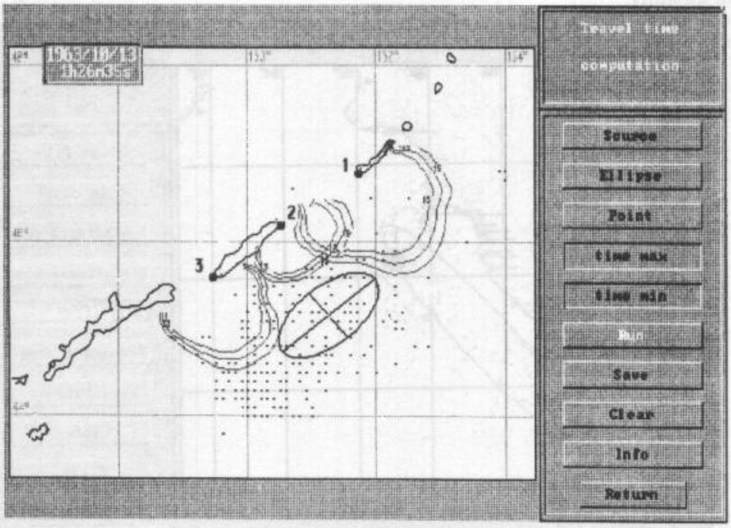

Fig.4. An example of application of the built-in modeling software - map of inverse isochrons for the event of October 13, 1963, calculated and plotted for three coastal points where observed travel times of this tsunami are available. Solid ellipse shows the estimated posituion of the tsunami source.

(3) it can be used as the basement for development of personal database for cientists involved in tsunami research and investigation.

The software developed under ETDB Project is the Data Base Management System (DBMS), menu-driven graphic shell for data retrieval and handling and the supporting mapping software. It runs on 286 or 386 PC under MS-DOS.

4. EDTB prototype

The demonstration version of the ETDB has been developed at the Tsunami Research Group of Novosibirsk Computing Center on the basis of historical tsunami database for the Kuril-Kamchatka region. It covers the area within 41.30' to 64.00' N and 130.00' to 168.00' E and consists of four main parts: earthquake database, tsunami database, geographical mapping and data processing subsystems. Two additional databases contain some basic reference information of the existing regional seismic and mareograph networks.

Currently, the earthquake database contains the source data of almost 42 000 events occurring within the region from 1737 to 1990. Source information includes date, time, coordinates of epicenter, depth, magnitude (basically Ms), and seismic intensity followed by indexing to data sources. All data can be cross-correlated and retrieved by geographical area, date, depth and magnitude.

The tsunami database covers the same period and contains 129 events with 115 of them having regional and 14 distant sources. Among 115 regional tsunamis, 105 have tectonic, 6 volcanic and 4 unknown sources. The tsunami data set consists of four main blocks: detailed source data of tsunamigenic events, coastal observations of tsunami wave heights, original descriptions of tsunamis and bibliographical references. Source data of tsunamigenic effects are cross referenced to the earthquake database but contain the extended set of magnitudes including moment-magnitude Mw, tsunami -magnitude Mt, seismic moment, moment-tensor and source mechanism (where available), tsunami intensity, maximum run-up height, position of tsunami source, validity of event, warning status and some other complementary information. The tsunami data can be retrieved by area, date, source magnitude and tsunami intensity. The information can be output in summary (condensed) or detailed (expanded) form. The latter includes all available observations of tsunami heights, periods, direction of the first motion, observed and calculated arrival time (where available).

The third part of tsunami database, which is still in process of compilation, contains comments, bibliographic data and the primary tsunami descriptions collected from original publications. Its main destination is to bring to the researcher the full initial descriptions of old events, some of them can be re-interpreted from a contemporary point of view.

6. Conclusion

Despite the ETDB is developed first for Kuril-Kamchatka region, it could be applicable and easily adapted to any other tsunamigenic region of the Pacific like Alaska, Hawaii, Philippines, Indonesia, South Pacific region, Chile, Peru, Ecuador, Mexico. At minimum cost it may be customized to the particular region of the Pacific and elsewhere (mainly, by extension of geographical database) after that the actual data compiling from the existing regional tsunami catalogs and other sources of data can be made in a relatively short term. A wealth of such data already exists but they are not properly organized, are not uniformly collected and are not readily available. Therefore, standards must be established for the collection of data and tsunami databases must be organized on a regional scale initially and shared on the Pacific-wide scale in later time. After the integration of all this knowledge into the expert database it will be widely used for real time operations in event mode and for tsunami risk assessment and mitigation in pre- and post-event mode.

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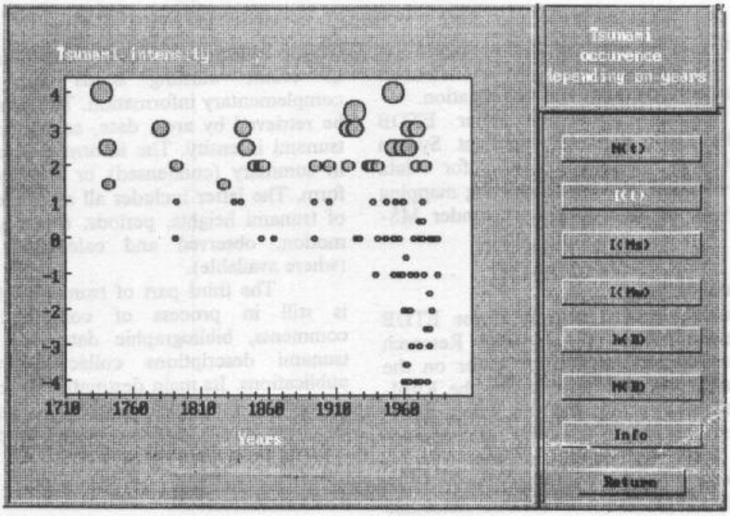

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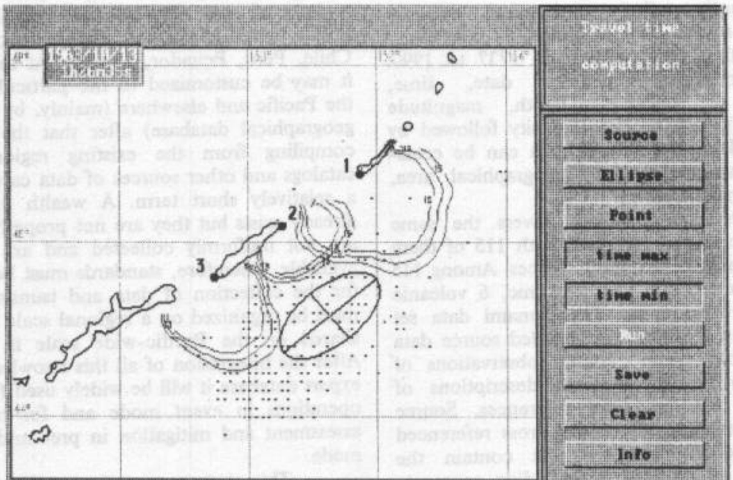

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REDUCTION OF EARTHQUAKE RISK IN THE UNITED STATES: BRIDGING THE GAP BETWEEN RESEARCH AND PRACTICE

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ABSTRACT

Continuing efforts, under the auspices of the National Earthquake Hazards Reduction Program (NEHRP), are underway in earthquake prone areas of California, Alaska, Puget Sound-Portland region, Intermountain seismic belt, New Madrid seismic zone, Southeastern and Northeastern United States, Puerto Rico-Virgin Islands region, and Hawaii to improve earthquake hazard and risk assessments, transfer technology, and reduce the risk. Scientists, architects, engineers, urban planners, emergency managers, and health care specialists are working at the margins of their disciplines to bridge the gap between research and practice by changing policies and practices for earthquake risk management.

INTRODUCTION

Earthquakes, although they occur less frequently than floods, landslides, wildfires, and severe storms, cause average annual losses of 1.5 billion in the United States. Most of the world's earthquakes occur along the Circum-Pacific or "Ring of Fire."

An assessment of the earthquake threat for a nation, a geographic region, a community, or the location of an essential building or critical lifeline or facility requires research to answer three simple, but highly complicated technical questions. They are: "where?," "how big?," or "how severe?," and "when?."

The answers to the questions: "where?," "how big?," or "how severe?," and "when?" quantify the geologic and geophysical parameters of the hazard environment. They specify: 1) the location(s) of the most likely future earthquake(s), 2) when or how often earthquakes of various magnitudes will occur at these locations, and 3) how severe the physical effects such as ground shaking, liquefaction, surface fault rupture, etc., induced by future earthquakes will be and their likely impact on the built environment. They give a scientific basis for changing community earthquake risk management policies and practices--the only way to reduce earthquake risk (Figure 1).

At present, geologists and seismologists can answer the question "where?" with a high level of confidence, but the state-of-the-art for answering the questions "how big?" or "how severe?" and "when?" is not as advanced. The state-of-the-art is based on the results of detailed studies of individual active fault systems using trenching, age dating, boreholes, strain and stress measurements, geophysical surveys, GPS measurements, and geologic mapping. The greatest problem, however, is that it is still not clear which geologic structure(s) caused some of the large- and great-magnitude earthquakes.

An assessment of the earthquake hazard (i.e., specification of the severity, temporal and spatial distribution, and probability of the occurrence of physical phenomena accompanying an earthquake) and risk (i.e., the chance of loss from these phenomena) is a complex task (Hays, 1991). Each assessment requires multidisciplinary investigations on national, regional, urban, and local scales. Both types of assessments are described below.

EARTHQUAKE HAZARD ASSESSMENT

Under the auspices of the National Earthquake Hazards Reduction Program (NEHRP) (enacted in October 1977, Public Law 95-124), earth scientists and engineers are working together to study: 1) plate tectonics; 2) faults; 3) seismicity,

Reduction Of Community Vulnerability

Built Environment
• Location, value, exposure, and vulnerability of buildings and lifelines at risk from earthquake physical effects (hazards) which can cause damage, failure, loss of function, release of hazardous materials, injuries, and deaths.

Hazard Environment	Policy Environment
• Physical effects such as: ground shaking; liquefaction; landslides; surface fault rupture; tectonic deformation; fires, and flood waves from seiche, tsunami, and dam break generated in an earthquake and the aftershock sequence; each potentially impacting people and the built environment in different ways.	• Social, technical, administrative, political, legal, and economic forces which shape a community's policies and practices for: earthquake risk management (i.e., prevention, mitigation, preparedness, prediction and warning, intervention, emergency response, and recovery), public awareness, training, education, and insurance.

Figure 1.--Essential factors for reducing community vulnerability to earthquakes.
historic earthquakes in the Eastern United States.

seismic sources zones, and earthquake potential; 4) soil response, and 5) ground shaking and ground failure. These studies are described below.

<u>Studies of Plate Tectonics</u>

Geologists and seismologists study plate tectonics on global and regional scales to answer the question, "<u>Why</u> are earthquakes occurring?" Each year, about 12 million earthquakes occur throughout the world. Most of these earthquakes occur along the boundaries of about a dozen 80 to 96 km (50 to 60 miles) thick rigid plates or segments of the Earth's crust and upper mantle. These plates are moving slowly and continuously over the interior of the Earth. They converge in some areas and diverge in others, moving at a relative velocity between plates that ranges from less than a cm (fraction of an inch) to about 25 cm (10 inches) per year. Although these plate velocities appear to be slow, they can add up to more than 50 km (30 miles) in only 1 million years, a short time geologically. As these plates move, strain accumulates until eventually, faults along or near the plate margins slip abruptly, producing an earthquake. Most of the world's earthquakes occur along the Circum Pacific. Alaska, California, and the Puget Sound-Portland area are located along the North American-Pacific plate margin and are the most earthquake prone parts of the United States. Intraplate earthquakes also occur in the Intermountain seismic belt, the New Madrid seismic zone, and the Charleston, South Carolina area.

<u>Studies of Faults</u>

Faults extending to the ground surface such as the San Andreas (a strike slip fault system) and the Wasatch fault (a normal fault system) are easy to identify and geologists and geophysicists have studied these faults and other like them to gain an understanding of fault mechanics. Those faults that do not extend to the surface such as the subduction zone thrust faults in Puget Sound, Washington; Alaska; Puerto Rico; and the buried fault systems in the New Madrid seismic zone in the Central United States and in the Charleston, South Carolina area are much more difficult to study. Collectively, these studies provide an understanding of <u>where</u>, <u>how big</u>, and <u>how often</u> earthquake are likely to occur. These answers provide a scientific basis for earthquake risk management policies and practices for construction sites near active fault zones.

<u>Studies of Seismicity, Seismic Source Zones, and Earthquake Potential</u>

Seismologists use networks of instruments in each earthquake prone area of the Nation to study earthquake activity (Figure 2) and to provide answers to the questions <u>where</u>, <u>how big</u>, <u>how often</u>, and <u>why</u>. Once seismically active faults and tectonic features in a region have been identified as a seismogenic source and characterized in terms of parameters such as maximum magnitude, recurrence rate, and seismic history, their potential for generating future earthquakes can be assessed and incorporated in hazard maps and risk assessments.

Figure 2.--Map showing locations of past notable earthquakes in the United States.

Although the exact mechanisms that produced some of the tectonic earthquakes in the Eastern United States are still in doubt, more than 100 discrete seismic sources have been delineated and characterized on the basis of seismicity and geologic structure. The correlation of earthquake potential with fault slip is clear along the Pacific plate margin, especially in California , but it is unclear at intraplate locations in the Eastern United States, especially in the New Madrid seismic zone of the Central Mississippi Valley and the Charleston, South Carolina area.

In August 1990 following the 1989 Loma Prieta earthquake, the U.S. Geological Survey's Working Group on Earthquake Probabilities reissued a 1988 report on the probability of magnitude 7 or larger earthquake in California within the next 30 years. It concluded that the probability is 60 percent in Southern California and 67 percent in the San Francisco Bay region.

Defining the earthquake potential in the Central Mississippi Valley region and Charleston, South Carolina region is a difficult scientific problem. Each region has low to moderate seismicity and a low annual probability for the recurrence of damaging earthquakes like those that struck the Mississippi Valley region in 1811-1812 and Charleston in 1886; the recurrence intervals are not only much longer but also more difficult to quantify.

Studies of Soil Response

The United States has many sites which have the geologic characteristics for soil-structure resonance. This phenomenon will occur unless an effort is made to prevent siting of structures on soils which will vibrate at the fundamental period of the structure. It is well known that the earthquake source generates seismic waves having a broad frequency spectrum; the path acts like a low-pass filter, attenuating the short period waves more rapidly than the long period waves. The soil column acts like a band pass filter, enhancing the periods that fall in a narrow spectral band and reducing those outside this band. A building also acts like a band pass filter, and when the period of the soil and the building are the same, damaging soil-structure resonance will happen, as it did in Mexico City during the 1985 Mexico earthquake and in San Francisco and Oakland during the 1989 Loma Prieta earthquake.

Studies of Ground Shaking and Ground Failure

Geologists, seismologists, and geotechnical engineers use portable and fixed arrays of strong motion instruments and a variety of field and laboratory techniques to learn all they can about ground shaking and ground failure both during and after an earthquake. When a fault breaks or ruptures, seismic waves are propagated in all directions from the earthquake source. As the compressional (P), shear (S), Love, and Rayleigh waves impinge upon the surface of the earth, they cause the soil and rock to vibrate at frequencies ranging from about 0.1 to 20 hertz (0.05-10 seconds). Ground shaking is elastic, and depending on the geometry and physical properties of the underlying or enclosing rock and soils, structures are induced to vibrate elastically and inelastically as a consequence of the amplitude, frequency composition and duration of the ground shaking. However, permanent ground displacements are inelastic; that are caused by surface fault rupture, liquefaction, landsliding, lateral spreading, compaction, or regional tectonic deformation.

EARTHQUAKE RISK ASSESSMENT

Risk assessments involve scientific, societal, and economic considerations (Figure 3). The main factors are: a) the location of buildings, facilities, and lifeline systems within a community, b) their exposure to the physical effects of an earthquake, and c) their vulnerability (i.e., potential loss in value) when subjected to these physical effects. Risk assessments result in a statement of the economic losses, deaths and injuries, and loss of function expected when a specific physical effect (e.g., ground shaking) strikes a given region, local jurisdiction, site, or structure. When the spatial and temporal characteristics of the physical effects are fully integrated with a community's existing inventory of buildings, facilities, and lifeline systems, the chance of loss can be determined. Risk assessments can be used to: identify hazardous geographic areas, groups of buildings, or lifelines; aid in the development of emergency response plans; evaluate overall economic impact on the Nation; formulate general strategies for land use plans or building codes).

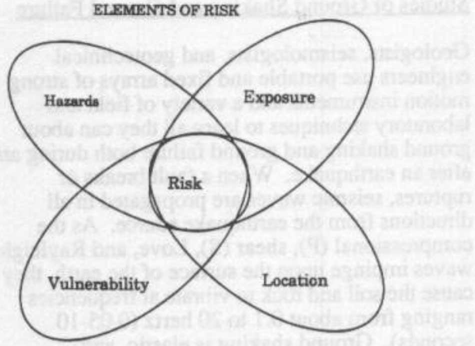

Figure 3.--Schematic illustration of elements involved in a risk assessment.

The physical effects (i.e., earthquake hazards) can damage or destroy buildings and lifeline systems (e.g., bridges, dams, pipelines, utility systems, tunnels, rapid transit) in urban centers and cause socioeconomic impacts over a broad geographic regions. Within a minute or less economic losses can reach several tens of billions of dollars. Ground shaking can trigger liquefaction (i.e., a temporary loss of bearing strength at locations underlain by young, loosely compacted, water-saturated sand deposits) and landslides (i.e., falls, topples, slides, spreads, and flows of rock and/or soil on unstable slopes). Some earthquakes will also generate surface fault rupture where, depending on the magnitude or amount of mechanical energy released at the initial rupture zone, the fault can propagate upward, and break the surface. Surface fault rupture, liquefaction, and landsliding cause permanent displacements, which can be especially damaging to underground lifeline systems. Regional tectonic deformation (i.e., changes in elevation over a broad geographic region) is a characteristic of great-magnitude earthquakes (i.e., those having magnitudes of 8 or greater). Tsunamis (i.e., long-period ocean waves generated by the sudden vertical displacement of a submarine earthquake) can generate flood waves that can destroy ports and harbors and buildings at coastal locations far from and close to the earthquake source. Tsunamis generated by submarine earthquakes have impacted Alaska, the Pacific coast, Hawaii, Puerto Rico, and the Virgin Islands. Seiches (standing waves induced in lakes and harbors), dam failures, and fires can also be induced by an earthquake. Aftershocks (i.e., smaller magnitude earthquakes, following the main shock) can occur for several months to years, repeating and worsening the physical effects described above, depending on their magnitude, proximity to the urban center building or lifeline or site, and the incipient damage state of the remaining structures.

Future earthquakes in either Northern or Southern California as well as the New Madrid seismic zone could cause economic losses that exceed $100 billion and kill and injure several thousand people (State of California, 1990).

EARTHQUAKE RISK MANAGEMENT

The term risk management suggest that earthquake risk can be controlled within limits set by the community. Community decisionmakers and professionals have to adopt and implement policies and practices that improve mitigation, preparedness, emergency response, and recovery. In many cases the existing capability within the community may be inadequate to carry out some or all of these risk management strategies. In those cases technology transfer is required to bridge the gap between research and practice. Mitigation refers to those actions that reduce the demands placed on the community by the natural hazard and/or that protect the community's capability. Preparedness refers to those actions that anticipate and reduce the demands and/or enhance and protect the community's capability. It includes prediction and warning. Emergency response refers to those actions that define the demands and/or manage and reallocate the community's capability. Recovery refers to those actions that stabilize the physical and social demands and/or actions that restore and improve community capability quickly. A disaster occurs when increased or extraordinary demands are made on the community and/or there is inadequate capability or a decrease in the community's capability to cope with the increased demands.

Through technology transfer, planners, emergency managers, medical service specialists, architects, engineers, and scientists can increase the capabilities they need for reducing the risk from natural hazards in their community. Urban planners plan the way groups of engineered and non-engineered buildings and lifelines systems will be combined to form streets and ultimately the urban center. Health care specialists and emergency managers organize the human and material resources of the community for emergency response and recovery. Architects design individual buildings, focusing mainly on the building configuration, non-structural elements, and occupant safety. Engineers, architects, and scientists work together to ensure that new buildings and lifeline systems will meet the requirements of the local building and land use regulations and withstand the physical effects of the earthquake.

Past earthquakes throughout the world have shown that communities are vulnerable to earthquakes because planners, architects, and engineers fail to adopt and implement policies and practices which experience has shown will make buildings and lifelines systems less vulnerable (Hays, 1993; State of California, 1990; EERI, 1989a and 1989b, 1986). A community benefits most from changes in policies and practices which enhance:

- Emergency preparedness and disaster recovery planning.
- Avoidance of the physical phenomena,
- Wise use of the land,
- Adoption and enforcement of building and zoning regulations,
- Reduction of vulnerability,
- Coordinated planning, siting, design, and construction practices,
- Modification of the characteristics of ground shaking and ground failure, and
- Prediction and warning.

Each of these applications is discussed below.

Emergency Preparedness and Disaster Recovery Planning

Emergency managers need realistic scenarios of what to expect and what to do in a damaging earthquake (Der Heide, 1989). These scenarios are the technical basis for emergency response plans and, in the case of a disaster that overwhelms the response capability of the community, disaster recovery plans. From past earthquakes, emergency managers have learned that a damaging earthquake will not only expose all of the flaws in policies and practices for siting, design, and construction of buildings and lifeline systems in the urban center but will also exhibit the weak elements of the emergency response and recovery plans. The most realistic response plans are based on the following assumptions:

- The earthquake will strike without warning at the "worst" time of the day and season of the year.
- Physical effects observed in past earthquakes having the same magnitude and location as the scenario earthquake will be repeated. (Note: Case histories of past earthquakes should be studied in detail to define the range of possible emergency response needs.)
- Ground shaking and ground failure will cause the greatest damage, social impacts, and loses. Fire, flooding from dam breaks or debris dams, and aftershocks should be expected to complicate the emergency response.
- The oldest and most densely populated parts of the urban center will suffer the greatest damage, highest losses, and the greatest

number of casualties and injuries. The poor and elderly will be severely impacted. Homelessness will be a major problem.
- The short-term physical, emotional, and social impacts on the populace will be varied and complex. Families will be separated, people will be trapped in collapsed buildings and highway structures, utilities will suffer outages, and huge traffic jams will be typical.
- Movement into and away from damaged areas will be hampered for days to weeks due to debris, damage to transportation systems, ongoing search and rescue operations (in the first few days), and postearthquake investigations (which can extend from weeks to months).
- Communications will be disrupted for hours to weeks and some communities may be isolated for several weeks. Coordination within and between organizations should be expected to be flawed.

To facilitate disaster recovery, the plans should be developed before the disaster in order to resolve issues that keep recurring in postearthquake recovery throughout the world. Some of the planning assumptions are:

- The political pressures will be very great because of the desire to restore the urban center and community services to normal quickly.
- Assessment of damage will be a top priority, but experienced people to make the assessments will be in short supply.
- Inspection and posting of "red" (unsafe, do not enter), "yellow" (caution in entering), and "green" (safe to enter) tags on buildings will be a critically important task charged with emotion and political pressures.
- Removal of debris will be a complicated task while search and rescue operations are underway and an urgent task during reconstruction.
- Rebuilding to improve the seismic safety of the urban center can be divisive politically; therefore, improved building and zoning regulations should be devised and adopted in advance.

Avoidance

The least expensive and most logical risk management strategy is avoidance. Planners should take the lead in identifying those locations in an urban center that are most susceptible to physical effects such as ground shaking, ground failure, surface fault rupture, and tsunami wave runup, and promote physical planning practices that avoid these hazards. Whenever possible, for example, physical plans should avoid locating buildings and lifeline systems:

- On soils having the same fundamental period of vibration as that of the building or lifeline system.
- In configurations where they will hammer or pound adjacent structures.
- On unstable soils susceptible to liquefaction and landslides.
- In locations subject to surface fault rupture, tectonic deformation, and flooding from tsunami wave runup, or a dam failure.

Wise Use of the Land

The local government, which adopts and enforces land-use measures and building regulations, always achieves earthquake risk reduction because it controls the only optional factor that governs destructiveness of an earthquake. The community has no options regarding control of: (1) the magnitude or energy release of the earthquake, and (2) the proximity of the earthquake source to the urban center. But it can control the extent to which land-use planning and building regulations have been implemented in the urban center to mitigate the effects of ground shaking, ground failure, surface fault rupture, and tsunami wave runup when the earthquake strikes.

Adoption and Enforcement of Building and Zoning Regulations

Planners, architects, and engineers have an important role in the adoption and enforcement of building and zoning regulations. Experience in past earthquakes has shown that economic loss, loss of life, and injuries are lower in urban centers that adopt and enforce seismic design provisions of a building code or urban development plans that consider the types and density of land use in areas prone to strong ground shaking, ground failure, surface faulting, or tsunami wave runup through zoning ordinances.

Reduction of Vulnerability

Damage and loss of function in a large city or capital city can be very disruptive to the State, adjacent States, and possibly the Nation. The capital is usually the headquarters and center for decisionmaking; political, administrative and cultural leadership; banks, insurers, and developers; and newspapers, radio, and television; and foreign embassies. Planners, architects, and engineers can reduce the vulnerability of existing development by application of structural and nonstructural measures in essential facilities such as schools, hospitals, and other buildings.

Coordinated Planning, Siting, Design, and Construction Practices

Planners, architects, and engineers have learned from earthquakes throughout the world that physical planning practices should be integrated with siting, design, and construction practices if buildings and lifeline systems are to withstand the physical effects of ground shaking and ground failure with a high degree of reliability.

Modification of the Characteristics of Ground Shaking and Ground Failure

Planners, architects, and engineers should work together to resolve problems associated with important new or existing civic, historical, or cultural buildings determined to be vulnerable to ground shaking or ground failure. For example, they can use base isolation technology to reduce ground shaking levels, and engineering methods to remediate soils and sites prone to liquefaction or landslides.

Prediction and Warning

Planners and emergency managers should collaborate with scientists who are monitoring pre-earthquake phenomena in order to predict the time, place, magnitude, and probability of occurrence of damaging earthquakes. At present, because the science of earthquake prediction is young, only intermediate- and long-term forecasts are feasible (i.e., a few years to a few decades). Planners and emergency managers should utilize the information contained in warnings associated with intermediate and long-term predictions to improve physical plans and emergency response and disaster recovery.

CONCLUSIONS

Under the auspices of NEHRP, continuing efforts are being made to keep the inevitable future earthquake from becoming a disaster (Figure 4). The emphasis is on improving earthquake hazard and risk assessments, transferring technology for earthquake risk management, and reducing the risk in every earthquake prone area of the United States. A technology base (i.e., information, knowledge, and know how) for earthquake risk management now exists, therefore, it is a matter of continuing the transfer of required technology to practitioners and fostering its implementation at the local level to change policies and practices.

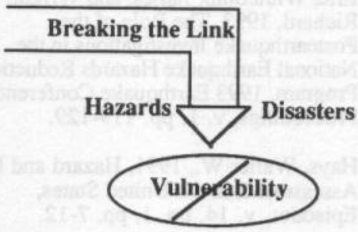

Figure 4--The goal of many communities throughout the world during the 1990's is reduction of community vulnerability to earthquakes (i.e., eliminates flaws in siting, design, and construction).

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ESTIMATING THE DEMAND FOR SHELTERING AND FEEDING IN FUTURE EARTHQUAKES AFFECTING THE SAN FRANCISCO BAY REGION

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ABSTRACT

The preparation for sheltering and feeding large numbers of people following a major earthquake is a critical social issue for the American Red Cross and San Francisco Bay area residents. Equivalent, simplified models were developed for Red Cross planners that integrated expert knowledge, damage estimates, and 1990 census socio-economic data. The assumptions and methodologies used in building the model and the results of using the model to analyze five scenario earthquakes in Northern California are discussed. The worst case scenario examined in the report is the Hayward combined (north and south) earthquake. The model predicts that approximately 120,000 people would require shelter and 260,000 would require mass care feeding in the nine county bay area based on this worst case scenario.

INTRODUCTION

This paper describes the results of a study designed to assist the American Red Cross Northern California Earthquake Relief and Preparedness Project (NCERPP), the Association of Bay Area Governments (ABAG), and the Bay Area Earthquake Preparedness Program (BAREPP) in establishing guidelines for risk area planning. The primary Red Cross function following a catastrophic earthquake or other major disaster will be to coordinate the delivery of mass care (sheltering and feeding) services. The ability to estimate service demands and mass care staffing requirements is, therefore, an essential first step for risk area planning. This paper develops a model and methodology for the estimation of the population requiring sheltering and feeding following an earthquake, and applies this model to five scenario earthquakes. The methodology uses as input data the results of the companion study completed by the Association of Bay Area Governments (ABAG) in April, 1992, *Estimates of Uninhabitable Dwelling Units in Future Earthquakes Affecting the San Francisco Bay Region* (Perkins, 1992). Sponsored by NCERPP and the Bay Area Earthquake Preparedness Project (BAREPP), ABAG modeled the damage for the five scenario earthquakes and estimated the number of uninhabitable dwelling units that would result from each scenario. The ABAG model was calibrated against the actual damage reports of the Loma Prieta earthquake. Feeding and sheltering demands are calculated based on the ABAG damage estimates.

BACKGROUND

The methodology described in this paper was developed by the George Washington University during two prior studies of Red Cross mass care service delivery for catastrophic events under the Federal Response Plan (Harrald et al., 1990, 1991). The modeling effort followed a three step process:

1. the estimation of the number of persons impacted by the disaster,
2. the estimation of the number of persons likely to seek public mass care assistance, and
3. the estimation of the number of service delivery units and mass care staff required to meet this demand.

The determination of the number of persons impacted by an earthquake requires the estimation of the damage done to structures and the calculation of the actual number of dwelling units contained by the impacted buildings. The estimation of structural damage is difficult since damage is dependent upon the intensity and duration of local ground shaking and the structural type of the building. The local ground shaking is a function of four parameters in addition to the magnitude of the earthquake: the underlying local geology, the depth of the epicenter, the duration of the earthquake and the distance from the fault. The predicted local intensity, given an epicenter and magnitude is, therefore, a stochastic variable. Differences in local geology will cause significant variation in local shaking intensity along iso-seismal lines. Precise information concerning building structural type is essential since most earthquake damage will be sustained by high risk structures such as unreinforced masonry buildings, pre-1940 wood homes, and mobile homes. The factors influencing the proportion of the population affected by earthquake damage are discussed in greater detail in Perkins (1992) and Harrald et al. (1992).

The San Francisco Bay area is unique in that excellent data on local geology and relatively complete structural inventories are available. . ABAG maintains ground shaking models as a component of its Bay Area Spatial Information System (BASIS) (Perkins, 1983, 1992). ABAG also maintains an inventory of existing building stock by construction type and number of stories. The ABAG report develops its damage estimates based on the intensity vs structural type damage matrices developed by Dunne and Sonnenfeld (1991). The availability of this data allowed ABAG to develop estimates of the number of uninhabitable (red tagged) dwelling units for each of the over 2000 census tracts in the nine county bay area for five scenario earthquakes as described in Perkins (1992), Steinbrugge et al., (1987) and Davis et al. (1982).

A MODEL FOR ESTIMATING MASS CARE SERVICE DEMAND

The ABAG estimates of damaged dwelling units for each census tract provided the essential initial data for the next step in the modeling process: the calculation of the population seeking shelter. When a family is made homeless by a disaster they may or may not seek public shelter or assistance. If they do require shelter, they may leave as soon as other alternatives become available. Prior studies have shown that the propensity to seek shelter is dependent upon damage levels, geographic area, and demographic variables such as income, age, and ethnicity. The U.S. Army Corps of Engineers and the U.S. Federal Emergency Management Agency (COE, FEMA 1990) found ethnicity and income to be good predictors of the likelihood of seeking public shelter following the evacuation of the North and South Carolina Coast during Hurricane Hugo. Milleti and Sorensen (1991) examined 23 incidents where public shelter was available and concluded that only the socio-economic status and age of the evacuees were predictors of shelter usage.

Models developed in studies prepared for the American Red Cross by the George Washington University in 1988 and 1989 used the expert opinion of Red Cross disaster managers to predict the likely behavior of affected populations. These models used the software package EXPERT CHOICE to integrate this expert judgement with demographic data and damage estimates in a hierarchical decision model. The integration of precise demographic data, approximate damage estimates, and subjective expert opinion into a useful predictive tool is a unique contribution of this methodology.

Several modifications were required to adapt the EXPERT CHOICE model for this project. First, the damage classifications were revised to reflect the classifications of ABAG. Three damage classifications were used: RED TAG--dwelling unit is uninhabitable; PARTIAL--dwelling unit sustains visible damage, but is habitable; NEGLIGIBLE--no visible damage. The number of red tagged dwelling units per census tract were calculated by ABAG based on the Dunne and Sonnenfeld damage matrices as described in the April, 1992 ABAG report. The damage threshold for producing homelessness is assumed to be approximately 20%.

The damage type variable formed the upper tier of the EXPERT CHOICE hierarchy shown in figure 1. The model was applied to each of the approximately 2000 census tracts in the bay area for all five scenarios. For each census tract, the percentage of dwelling units in each category (red tag, partial, negligible damage) as determined by ABAG was used as the weighting factor.

The next step in the modeling process was to use Red Cross experts familiar with the bay area population and bay area disaster to estimate the relative importance of each of the socio-economic variables (income, ethnicity, etc.) as predictors of the likelihood of seeking public shelter for each damage type. The estimates made by the experts were merged by eliminating extreme values and then calculating mean values. These estimates became the weights for the second tier of variables shown in Figure 1. The model provides a consistent method of integrating the weights for damage type that are based on data (ABAG calculations) and the weights for the relative importance of the socio-economic variables that are based on expert opinion.

The third tier of the hierarchical model represents the actual socio-economic description of each census tract. The variables used were: Income distribution (discrete increments), ethnic type (white, black, hispanic, Asian and other), age (% under/over 65) and type of residence (owned, rental, vacation). The values for these variables for each census tract were obtained from the Donnelly Marketing CONQUEST system and represent 1990 demographic projections.

This modeling technique assumes that the distribution of socio-economic groups across the eight building types within the target geographical area is uniform. This assumption is certainly not true for a large geographical area such as a city or a county and is the reason that the smallest possible geographic area (census tract) was used as the basis for the analysis. The use of geographical areas larger than census tracts would have required assumptions of uniformity that clearly are invalid. The average number of persons per dwelling unit for census tracts in Alameda county, for example, varied from 1.2 to 5.1 and the percentage of families with income less than $10,000 per year ranges from 0 % to 60%. The final level of the hierarchical model was supplied by expert judgement. Red Cross experts were asked to provide their estimate of the percentage of a population segment described by two variables: damage level (red tag, partial, or negligible) and Socio-economic (income level, ethnic type, age). The methodology implies two important assumptions: (1) the experts could consider the effect of the socio-economic variables independently, and (2) considering the variables independently would not introduce significant computational error. Variables such as income and ethnicity are clearly correlated in the urban areas under study. Experts had some trouble separating the variables, but were able to provide consistent and useful information interacting with the EXPERT CHOICE model. The expert judgements were again merged by eliminating outlying values and calculating mean values.

The EXPERT CHOICE model was very useful for structuring the problem and for interactively extracting expert judgements. It would, however, have been extremely difficult to solve since a separate model would have to be constructed for each of the 2000 census tracts. The problem was transformed into a reasonably straight forward, albeit cumbersome, form that enabled it to be solved using a micro computer based spreadsheet. The mathematical formulation of the problem is essentially a weighted Bayesian probability analysis.

The estimation of the proportion of the affected population that will seek public feeding was based on the estimates of the population requiring shelter as described in Harrald et al. (1991). The population that requires feeding services will consist of four groups. A description of these groups and a first approximation of the percentage of each group that would seek feeding services following a major earthquake, based on interviews with Red Cross disaster services personnel are as follows:

1. Persons in Shelters: 100%
2. Persons displaced from red tag dwellings, but not in shelters: 50%
3. Persons still in partially damaged homes, without the ability to obtain and prepare food: 10%
4. Disaster workers: 100%

The estimates of demand for sheltering and feeding were adjusted upward to account for two factors: the pre-disaster homeless, and seeking of public services by people in habitable dwellings due to interrupted water, electricity, and natural gas service. The method of making these adjustments is described in Harrald et al. (1992).

RESULTS OF MASS CARE DEMAND MODEL

Demand for sheltering was calculated for each of the five scenario earthquakes used in the ABAG study: the peninsula segment of the San Andreas Fault, Hayward Fault Combined, Hayward Fault North, Hayward Fault South, and the Healdsburg-Rogers Creek Fault. A summary of the results is shown in Table 1. The maximum projected shelter population is 120,153 resulting from the Hayward combined scenario; the minimum is 23,380 resulting from the Healdsburg--Rogers Creek scenario. The model projects that 68,695 victims will require shelter in Alameda County following a Hayward combined scenario earthquake. The shelter population estimates for Alameda following a Hayward North event (48,012) and Hayward south event (33,614) and projections for Contra Costa county for the Hayward combined and North scenarios ranges (13,029) show that the East Bay event will provide the worst case scenarios for the bay area. The shelter population anticipated in San Francisco County ranges between 10,000 to 15,000 for the Hayward scenarios. The San Andreas peninsula scenario is primarily a West Bay event, resulting in projected shelter populations of 11,253 in San Francisco county, 6,370 in San Mateo County, and 8,842 in Santa Clara county.

SOURCES OF ERROR AND UNCERTAINTY

The results of all modeling efforts should be interpreted with a degree of skepticism. The joint ABAG and GWU project has attempted to make a first approximation to some of the critical impacts of a northern California earthquake. The results are useful, but highly uncertain. Any model is a selective representation of reality. All models leave things out; and the validity of a model is limited by the modeler's ability to make simplifying assumptions while still capturing significant variables and relationships. A major simplifying assumption in most models is the treatment of uncertainty with deterministic variables or artificially constructed probability distributions. Sources of uncertainty and error include the following:

1. Parameters that describe the basic earthquake event are stochastic. The following factors will

influence the intensity of local ground shaking: e.g., the duration of the earthquake, the depth of the epicenter, and the location of the epicenter along the fault.

2. The intensity of the local ground shaking depends upon the local geology. Although the local geology in the Bay area is known and mapped with a higher degree of accuracy than most areas in the United States; in other areas, the precise type of local geology and its response to the earthquake are not known with certainty.

3. The estimated response of buildings to a given level and duration of shaking intensity is a stochastic variable. There is significant uncertainty in the relationship between damage, shaking, intensity, and structural type.

4. Significant potential sources of uncertainty and error are introduced in the GWU model through the use of expert judgement. The model treats highly correlated variables (e.g. income, ethnicity) as independent making it difficult for experts to provide valid input and introducing potential computational errors.

5. The behavior of the disaster victims is inherently a stochastic variable. The same population may react in very different ways to similar events depending upon external factors such as news coverage (or inability to get information), and political leadership (or lack thereof).

CALIBRATION AGAINST LOMA PRIETA

An attempt was made to calibrate the modeling technique used in this study by comparing the actual Loma Prieta earthquake shelter populations with the shelter populations calculated by the model. Loma Prieta peak shelter populations for San Francisco, Alameda, and Santa Clara counties were obtained from the Red Cross records and the actual number of Red Tag dwellings and the estimated number of dwellings sustaining partial damage was obtained from ABAG. The predicted number of persons seeking shelter from these damaged dwelling units was calculated using the ABAG damage model and the GWU demand model.

The actual experience in Loma Prieta was approximately 35% of the shelter population predicted by the ABAG-GWU model. Although the model may appear to severely overestimate, it should be noted that the Loma Prieta event was less severe than any of the scenario earthquakes and comparatively little infrastructure damage actually occurred. Population could in fact seek alternative shelter outside of area. In addition, the Loma Prieta event was of relatively short duration and partial damage estimates used to calculate expected shelter populations are probably high.

CONCLUSIONS

The preparation for sheltering and feeding large numbers of people following a bay area earthquake is a critical social issue. Based on USGS data, "The combined probability of one or more of these earthquakes occurring is 15% in 5 years, 33% in 10 years, 50% in 20 years and 67% in 30 years." (ABAG, 1992, p.6). The models constructed by ABAG and The George Washington University, provide an initial point for disaster relief planners and provide an insight into the factors that influence the demand for mass care services. In particular, the GWU model shows the importance of preparedness activities. Persons in partially and negligibly damaged dwelling units will not need to seek public shelter or feeding if they have stockpiled food and water in their home and are prepared to be self-sustaining for several days. In areas without adequate education and preparedness programs, these populations could quickly overwhelm relief facilities.

Data available in the bay area allowed ABAG and the GWU to make reasonable estimates of earthquake damage and mass care service demands. This information is critical to the development of Federal, State, and Red Cross disaster plans. The modeling efforts initiated by the Red Cross, the Bay Area of Governments and The George Washington University should be refined and applied to other risk areas. Critical work in other risk areas will be the creation of structural inventory and local geology data bases that correspond to the data maintained by ABAG.

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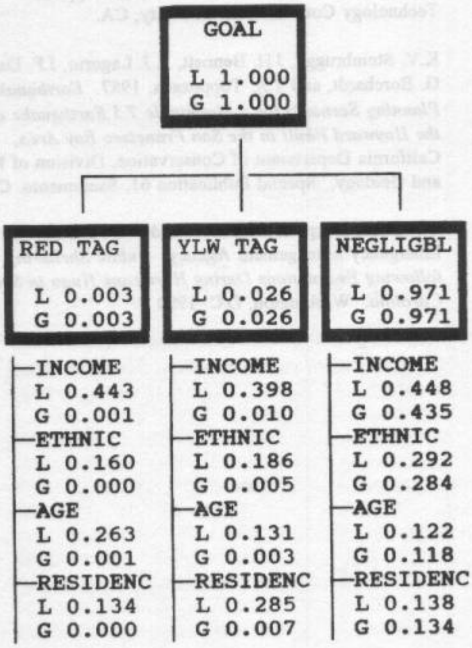
FIGURE 1: EXPERT CHOICE MODEL FOR PREDICTING THE PERCENTAGE OF HOUSEHOLDS THAT WOULD SEEK SHELTER FOLLOWING A BAY AREA EARTHQUAKE



RED TAG: % OF DWELLINGS UNHABITABLE
YELLOW TAG: % OF DWELLINGS PARTIALLY DAMAGED
NEGLIGIBLE: % OF DWELLINGS WITH NO OR MINOR DAMAGE
INCOME: INCOME DISTRIBUTION OF HOUSEHOLDS IN AFFECTED AREA
ETHNIC: ETHNIC DISTRIBUTION OF POPULATION IN AFFECTED AREA
AGE: AGE DISTRIBUTION OF POPULATION IN AFFECTED AREA
RESIDENCE: DISTRIBUTION OF RESIDENCE TYPE (OWN, RENT, VACATION) IN AFFECTED AREA

TABLE 1: SHELTER POPULATIONS FOR SELECTED EARTHQUAKE SCENARIOS BY COUNTY

COUNTY	SAN ANDREAS/ PENINSULA	HAYWARD COMBINED	HAYWARD NORTHERN SEGMENT	HAYWARD SOUTHERN SEGMENT	HEALSDBURG RODGERS CREEK
ALAMEDA	2,614	68,695	48,012	33,614	1,735
CONTRA COSTA	72	13,029	13,029	1,056	626
MARIN	614	1,150	1,150	620	984
NAPA	8	98	98	11	335
SAN FRANCISCO	11,253	14,904	14,904	10,316	5,656
SAN MATEO	6,370	896	493	896	50
SANTA CLARA	8,842	20,179	1,151	20,179	59
SOLANO	395	921	921	540	876
SONOMA	38	281	281	46	13,059
TOTAL	30,206	120,153	80,039	67,278	23,380

NUCLEAR EMERGENCIES

ETH - RISK: a Pilot Knowledge and Decision Support System for Nuclear Power Accidents Emergency Management

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Abstract:
ETH-RISK is designed as modular, expandable, articulated, GIS- oriented platform, capable to accomodate and test a variety of models- mathematical and logical- normally concuring in the risk and accident consequence assessment as applicable to nuclear power plants. The current version of the software, drawing upon a preliminary concept developed by one of the authors (D.V.), combines expert system and GIS features into an early-response-oriented Knowledge Based and Decision Support System. It also combines pre-digested knowledge and casuistry with ad-hoc analysis to diagnose abnormal events, evaluate the amplitude of the entailed environmental contamination and potential health effects, and have these mapped together with the zones of recommended intervation, including the points of minimum risk. ETH - RISK is believed to hold good potential for steering a many-folded development: towards a DSS, computer assisted learning and expertise instrument, transparent to mitigate several expert-to-decident communication problems in Emergency Management.

1. INTRODUCTION

The archetypal severe nuclear accidents, Three Mile Island and Chernobyl have revealed the singular importance of the availability of Knowledge Bases and Decision Support Systems (KB-DSS) for an efficient emergency planning and management of nuclear crises. At the origin of this situation is the demanding nature of the main task in severe accidents' management; to cater for masses of people in distress in manners that would not add too much to the hardships already confronting them. A number of factors would further stress this deontological must, such as:

i) the fact that no two accidents are exactly alike, abnormal nuclear events featuring a variety of possible initiators and sequences that are rich in potential bifurcations, commensurately with the inherent complexity of the nuclear technology;

ii) the unusually wide margins of uncertainty within which measurements, diagnosis and prognosis must carve a path to decisions on protective/ corrective action, to the extreme extent of talking the consequences of an accident the source term of which may never be actually known - the least in its most critical, early phase; and betting high on a whimsical meteorology;

iii) the crucial importance of the time factor in deciding upon, and implementing the early countermeasures (e.g.sheltering, administration of stable iodine, and evacuation);

iv) the comparable importance of the space scales, and site specificity insofar as terrain's relief, canopy, climatology, demography, exposed property, social habits, behaviour and reactivity etc. One difficulty bears on the quest for a near-real time response from the advisory machines on the one hand, and the need to decently account for complexities including e.g. source terms, a variable in time and territory meteorology, and a terrain of tortuous relief and patchy canopy, demography.

As proven in actual practice, this has a counterpart in communications (man-machine and man-to-man). Recent analyses /1/ have concluded that such conflicting demands "cannot be fully resolved, but the approach chosen should be an acceptable compromise between the requirements for scientific rigour, flexibility and easy adaptation to user's needs". ETH - RISK is a computer software for accident consequence assessment, KB and GIS oriented platform capable to accomodate a variety of mathematical and logical models in risk and NPPs accident consequence assessment . The software interfaces its User to a Knowledge Base consisting of (i) rules derived from knowledge pre-digested in Accident Response Manuals (ARM) issued by nuclear regulatory bodies and/or utilities; and (ii) algorithmic expressions of logical and mathematical models of the phenomenology typically accompanying a nuclear accident, from the occurence of an initiator down to a radioactive release, its environmental dispersion and consequent effects. ETH-RISK does not ignore the existance and continual improvement of emergency management software. The contrary- the exercise to develop this software is precisily motivated by an awareness on the issues that so far prevent the adoption of any single DSS as a universal, crisis management tool. The coverage: of time and space scales (early/intermediate/late accident phases, near site/regional assessment):of site and environmental typology (the source term: reactor, waste repository, UF6, fire/ non-fire source, transport; singular burst/protracted, long duration release: release including/not including activities); ii) trading off DSS complexity vs. practicality, accuracy vs. near-real-time capability; iii) communications quality (expert-to-layman-decident, and the public at large; man-to-machine and vice versa); iv) compliance with national / international standards, norms, practices, behaviour, legislation; v) deontological constraints: (dose minimization vs. as-low-as-reasonable adequate intervention; having the machine advising, never deciding).

ETH-RISK is an experiment; it accomodates postulated/ simulated source terms, environmental dispersion under a variable in time and space meteorology, complicated terrains and aims at enhancing event diagnosis capabilities and heuristic modelling in line with currently perceived needs in the Emergency Management trade.

2. ETH-RISK's STRATEGY

ETH-RISK's philosophy and strategy stem from the paramedical approach to intervention in case of individual - collective health crises. At the core of its spirit is a handful of common sense principles, such as:

Rule a: First aid comes first, the full clinical investigation and intervention - later.

Rule b: Base first aid on fast anamnesis - if feasible -, and fast symptom analysis, both conducive , yet not iretrievably commital, diagnosis.

Rule c: Move fast. Have a limited yet proven inventory of relevant diagnostics ready for use, together with corresponding sets of "golden rules" that may ease the crisis till more profound measures can be initiated.

Rule d: Make all steps taken amenable to the understanding and co-operation of all actors involved;

Rule e: Base your tool kit on pre-digested knowledge; ***experience;*** and ***expert judgment.***; make extensive use of response manuals; considered "best guesses"; postulated prognosis (scenarios); simulation exercises; heuristic associations; accumulated casuistry.

Rule f: Adopt a deontology of *As Low as Reasonably Adequate (ALARAd?..)* intervention; until full clinical investigation and lab analyses are properly done, chances of ill-advised intervention remain high, which may synergistically amplify the costs - human, financial and material - of crises.

Rule g: Keep yourself in good fittness -- which also implies keeping your tool kit up to the state-of-the-art. ***Don't trust low probabilities when risks are high: try and anticipate as many "worst cases" as imaginable/tractable. The least expensive and also safest way towards a "near-real time" tool is to remove the bulk of work from the crisis time into the training time.*** There is such a thing as the "crisis stress sydrome", that is likely to cut emergency managers' abilities by sensible fractions.

Observation : Working in anticipation of the worst is one safe way to shield yourself against the crisis stress syndrome.

Comment 1: ETH-RISK is an early-intervention oriented tool meant to offer guidance and support to managers' reaching minimally informed decisions on the most time-sensitive action normally expected in an off-site consequences entailing nuclear accident: activation of crisis management entities; assuming of legally-enforced postures and action station by the chief actors; early alert; and application of early countermeasures.

Comment 2: ETH-RISK would operate on the principle that, in the event of a severe nuclear accident, everybody in an undeterminedly wide proximity of the source would get something out of the release. Problem is who is likely to get more, where and when. ETH-RISK shows field operators where to act first, when, and how. ETH-RISK is primarily after : the Most/Least Exposed Areas in a target-territory; the Paths of Minimum Exposure; *de minimis* Alert terms of reference, such as cloud's Estimated Arrival and Exit Times and Maximal Expected Local Activity Excursion; thematic mapping of Zones of Recommended Application of Early Countermeasures, and of potential health effects (risks).

Comment 3: ETH-RISK (i) offers the User an interactive, expeditious input machinery; (ii) sufficient explanatory assistance at run time; and (iii) pictorial, expressive and readable outputs as far as feasible. Most ETH-RISK outputs are in form of maps - of contrasting exposure, contamination, and intervention zones, super-imposed on geographical maps that may readily be rendered in a 3-D perspective, as probably one of the most informative and intelligible manner to address laymen decidents and guide field operatives.

Comment 4: ETH-RISK would also try to show itself sensitive to human nature. It cross-examines its partner, confronting him with human's appraisal/reasoning flaws, incongruences, inconsistencies etc. amounting to conflicting diagnostics. It will always leave final decision to its human counterpart. Reiterations, and the quest for alternatives are built in the human nature; ETH-RISK would considerately provide for these, too.

Comment 5: ETH-RISK is a modular, open structure that may - and will - assimilate in later phases of its development components that will go deeper into the accident's time to its Intermediate and Late phases, dealing with food restrictions, health effects categorizing and assessment, assessment of economic losses, cost - benefit analyses of countermeasures effectiveness, projections and planning of corrective actions for environmental and property reclamation etc.

Comment 6: The long way of ETH-RISK's towards growing into a full operational tool would take interested developers and users through much model refinement and augmenting; intensive testing, aiming at error trapping and improved logical articulation; site-customizing and validation through field experiments.

Comment 7: The ETH-RISK exercise has taken up a principle of non-intrusion: pilot platform to put on trial various concepts in Emergency Management.

3. ETH-RISK's MODELS

To implement its early-intervention oriented strategy, ETH-RISK selectively embraces two conventional approaches, namely:

i) The dose-oriented approach, geared to the effective determination of dose rates and committed doses to critical groups, relying on the appropriatenes and completeness of Dose Conversion Factors (DCF); and

ii) The derived intervention levels approach, geared to the determination of time-integrated concentrations in air and time-integrated depositions, and the expeditious comparison of these with the intervention levels recommended by the IAEA for such directly calculable and measurable environmental impact quantities (Derived Intervention Levels-DIL). The uncertainties and many sources of error would then shift from the DCFs to the DILs, particularly having in mind the delicate task of site-customizing DILs.

Other distinction in ETH-RISK is between logical models and mathematical models. While the logical models are algorithmic expresions relying upon the Boolean algebra and IF...THEN...ELSE rules, of the fault and decision trees describeb in Accident Response Manuals, the mathematical models would capture in evolution-and other equations the release of radioactivity, its environmental transport and dispertion, and the lines between the environmental contamination and the recommended interventions zones, as well as the dose distribution and respective, expected health effects. The interweaving between the above criteria is rendered in Figure 1. A distinction is made in ETH-RISK, between: i) consequence assessment in the near-range around release sources; and, ii) consequence assessment at regional scale. The main differences concern the assumptions on the weight the terrain might have in driving the dynamics of the radioactive clouds/plumes: high and decisive for the near range that is dominated by the notion of termo-hydro-dynamically distorted flows, and less consequencial at regional scale - where mesoscale circulation and dispersion would call the rules and odds.

3.1. Logical Models in ETH-RISK

Figure 2 is self-explanatory; the various expressions may take across a process that starts with the factual realities of life and ends up into the Analyst/ Decident's mind, via the DSS; the crisis stress syndrome normally striking Emergency Managers in no-drill situations. Managers are prone to making erroneous use of the intricately articulated knowledge in Manuals, generally based on fault tree analyses, and/or may need more time than acceptable to reach the right verdict on events and identify the respective required actions. Facing these, an automated exploitation of Response Manuals have appeared as the next natural step with streamlining DSS sessions by further transferring part of the analysis effort into the preparedness area. The automated diagnosis of an abnormal event in a plant, followed by an automatic verdict on what action should be immediately taken, was termed a 'Synthetic Diagnosis'. The implementation of the Synthetic Diagnosis scheme required i) a convenient algorithm to articulate the logical values along and across the fault trees described in ARMs, and ii) a user-friendly code to make algorithm(s) work. The algorithms made extensive use of IF...THEN...ELSE clauses and pertinence matrices, while codes tried and reflected the typical human perception on how a diagnostic can logically be reached - that is, through anamnesis. The first steps into an ETH-RISK DSS session comprise:

i) A statement from the KB-DSS Operator, given in natural language, on whatever (apparently) happened that made him activate the KB-DSS.

ii) A message analysis by the Machine searching for relevant keywords, either directly belonging to the trade's idiom (e.g. 'pump', 'coolant', 'valve'), or suspected to be reflective of crisis situations ('casualties', 'loss' etc.). A ***de minimis*** set of keywords was provided, in the Machine's Basic Lexic bank.

iii) An anamnesis of the Operator by the Machine, in consideration of the message received. In its current version, the code would start firing pertinent questions to the Operator. The pre-formatted questions are reflective of the investigative logics of the RTM-91 Response

Technical Manual Vol.1, Rev.1 - April 1991 by the US Nuclear Regulatory Commission /2/. Accepted answers are 'yes', 'no', or 'don't know'. Different key-words were contextually organized in the structured lexic so that returns to the same machine 'suspicions' were made possible. Graphic examples may be 'pump', 'line', 'valve', 'pressure' etc. that would trigger related, yet not necessarily identical querries. The more fuzzy a term, the higher the number of queries raised by the Machine in its trail - to the extent that one of the most unclear yet disturbing word, namely 'problem' is bound to trigger almost all the available questions in stock, till the answers would zero-in upon a clear diagnostic. Cross-examinations are then conducted by the Machine using alternative approaches described in ARMs,.to consolidate the diagnosis. In the process, conflicting diagnostics may occur on the account of the near-impossibility to develop a simple and full-proof speech / text analysis algorithm. Such conflicts should be resolved by the Human Factor only; ETH-RISK should advise, yet never decide.

iv) Once a synthetic diagnostic is reached, the machine would deliver this in the form of an alert grade. Possible grades are:(1) Notification of an Unusual Event, (2) Alert Status, (3) Site Area Emergency, or (4) General Emergency. Each grade would attach a number of response recommendations and rules of conduct, on-site as well as off-site, for accident managers in different positions. Room for 'Events below Scale' was also reserved.

3.2 The Mathematical Models in ETH-RISK

Mathematical models in ETH-RISK originate in the general notion of transport phenomena. A tractable solution to the flow motion in complex terrain was designed; it was based on a heuristic parametrization of the original Navier-Stokes equation. Key to modelling the complex terrain's influence on flow motions was the introduction of the terrain-distorted "pressure" field parameter. A tensor is coupling the "pressure" gradient components features and a "plan" component that is proportional with the local angle between Sun's direction at each moment and the normal to the terrain in the respective spot. An inversion lid oscillating between midnight and mid-day and small eddy turbulance were also introduced in the model. It is precisely the interplay between the inversion effects and the driving forces induced by the insolated terrain that result in determining released puffs trajectories. Flow's large eddying in hydrodynamic cavities, blockin, deflection, "chimney" and "canion" effects, and other characteristic behaviour is well acounted for by the model, under the control of essentially two parameters- a characteristic length, and a friction-related quantity that are to be adjusted according to the rugosity of the terrain. To descriebe puff dispersion in the trajectory model, a fractal structure of the released clouds was assumed, in the same sense that around the main puff center evolving along its trajectory mini-puffs are generated in three dimensions following a gaussian spatial distribution with Doury coefficients. In turn, each minipuff features itself an identical, interior, gaussian distribution. Ground reflection and deposition are provided for in the model, in latter being discussed in terms of frequency and velocity. The effect of precipitations is also accounted for. This near-range trajectory puff model generated in a probabilistic mode-assuming gaussian distributions of particle masses, wind directions and speeds around referance values, or in a deterministic mode, when release rates, wind directions and speeds are user-given. Wind rose distributions of wind directions can also be descriebed. A plume rise model is also incorporated. At regional scale a multiple straightline gaussian model of plume dispersion, or again a couple of puff models can be considered to obtain maps of time - integrated concentrations, time-integrated deposition on ground, intervention zones, doses and effects. This time models would rather use closed formulas for the integral solutions of the advecting-diffusion equation, integrated in time using K-Bessel functions. The dry and wet cloud deplation and deposition are all related to the Bonka and Horn approach, whereas for the gravitational setting a scheme proposed by Bridgmann and Bigelow was used. A fraction of plume's conformity with the terrain was assumed to take care of complex terrain effects at this much larger scale. An enhanced flexibility provides for griding in both space and time not only the eulerian wind field (direction and speed), but also the precipitations, the atmospheric stability, and the vegetation. Four point bi-variate interpolations are used in a pixel-by-pixel rendering of ETH-RISK's thematic maps.

3.3. Mixed models: Logical and Mathematical

Models in ETH-RISK are, unavoidably, mixtures of logics and mathematics; there is one section of the code package where the such mixture is of essence. It deals with accident source terms. SOURCE.ETH-RISK - is another expression of the Synthetic Diagnosis strategy as explained. Basically, it is a source term indirect diagnosis module that relies on plant condition analysis. Pictorial viewgraphs of five standard types of US reactors (PWR dry containment, PWR ice condenser containment, and MARK1, 2, and 3-contained BWRs) are called together with the most critical points that are prone to accidents with potential consequences. Affected

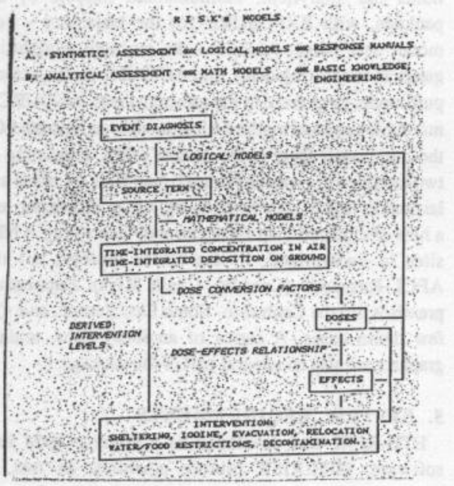

Figure 1

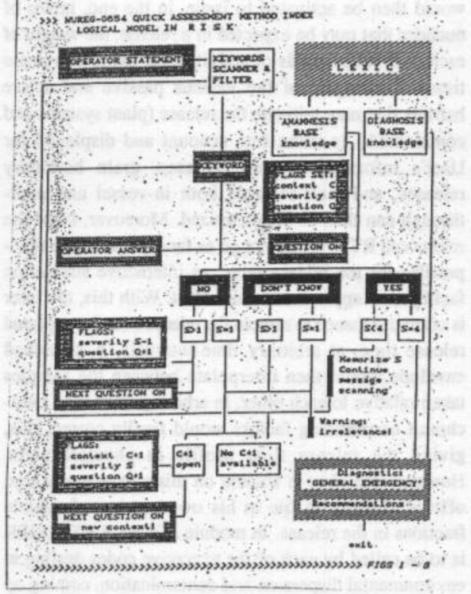

Figure 3

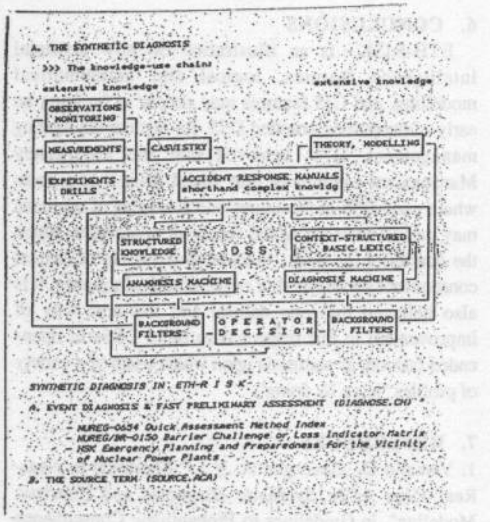

Figure 2

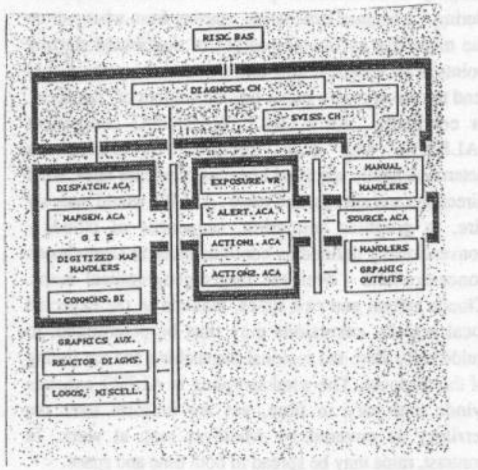

Figure 4

spots are to be marked on a move-cursor basis. The RTM's inference machinery that was cabled into the code would then be activated to issue, in the end, tables of nuclides that may be expected in a release, the weight of each, and summ totals of activity over expected release times. The logics of the various passive and active barriers that may mitigate the release (plant systems and containment) is taken into account and displayed for User's information. Gap releases, grain boundary releases, and melt releases both in-vessel and melt-through can thus be characterized. Moreover, since the referenced RTM would not go as far as to prescribe time-profiles for the release rates, an interactive simulation facility was appended to this effect. With this, the User is offered a chance to sample the release over the expected release time, at arbitrary time-intervals. A smoothed envelope would then interpolate between the samples taken relative to each other, in arbitrary units, and User-chosen normalizing factors would finally correct this, giving the release time profile in physical units. However, the User is warned on this circumstance, and offered chances to file in his own version of nuclide fractions in the release. In module SOURCE.ETH-RISK is to be called by each of the executive codes dealing in environmental dispersion and contamination, coming up next. An essential aspect about ETH-RISK is that, for its largest part, it is patterned in a GIS style. Figure 3 explains that only the components declared in bold case are operable. Several other aspects about code's facilities may be worthmention. One facility is for User to roughly determine the paths of minimum exposure during a presumed evacuation, starting from wherever on the map. If a sufficient number of distributed starting points is so tested, it will turn out that the paths would tend to converge to a rather limited number of "families", or corridors. An EARLY WARNING component (ALERT) was also designed. Working on deterministically specified histories of release rates, wind directions and speeds, and rains , ALERT would basicaly fire, in graphics animation, sequences of clouds - conventionally defined by contours taken at User-chosen concentrations - over the target geographical maps. Clouds arrival and exit times, maxima in the expected local activity excursions may thus be determined, to guide early alert, the regional dispatching and the timing of the response. The wind sampling in ALERT assumes winds that vary in time, yet are uniform over the territory as covered by whatever map at work. In contrast, rains may be spread in both time and space.

4. ETH-RISK's STRUCTURE

Figure 4 gives the ETH-RISK's modular structure. The upper floor (DIAGNOSE.CH, SWISS.CH) make the "synthetic diagnosis" section, the middle level-center holds the analytical, mathematical models of the package, with EXPOSURE for the trajectory - puff model near range, ALERT - the multiple straightline gaussian model (regional), and ACTION2 the trajectory-puff model (regional). In the executive area is SOURCE, mixing logical and mathematical models as indicated.On the middle-left level is the system's GIS, consisting of two facilities to generate numeric map files for relief and landmarks (roads, state borders, etc) a map dispatcher, and a host of digitized map files, currently describing i) NPP sites in Switzerland, ii) the Swiss teritory, iii) the AECL-Research (Canada) Chalk River Laboratory premises, iv) the Central-to- South East Europe, and v) a few demo cases. A series of ancillary files, mainly graphics are also an integral part of the package.

5. SYSTEM REQUIREMENTS

ETH-RISK was developed as a portable IBM PC-software. ETH-RISK prefers machines as fast as available. A coprocessor, whether independent or integrated into the motherboard (models 486 and up) is of essence, as is a fast clock. Users are advised to not even try ETH-RISK on anything below 33 MHz. Colors are of consequence with ETH-RISK.

6. CONCLUSIONS

ETH-RISK is an illustration on how artificial intelligence features, logical and mathematical modelling, and GIS features may concur in building an early - intervention oriented DSS for nuclear emergency management. It is believed that the Emergency Management community may found it itself at a point where good DSS architectures and strategies of response may prevail over the naked technical proccesses. Since the quality of the man - machine interface is of critical consequence for the quality of the DSS performance, it is also believed that one natural and low-cost way of improvement in this respect is to build DSSs in open-ended fashion, as platforms upon which users of a variety of profiles "learn by doing".

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A DATABASED DECISION SUPPORT SYSTEM FOR NORWEGIAN NUCLEAR EMERGENCY PREPAREDNESS

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Abstract

In order to be prepared to handle a nuclear emergency accident situation the Norwegian Government has established a central emergency organization. Considering the vast amount of information and data needed to keep an updated overview of a nuclear emergency situation, this central emergency organization needs an efficient information an retrieval system. Accordingly the Norwegian Government has decided to develop a computerized system for continuous monitoring and decision support in an accident situation. This system is called NORMEM (Norwegian Major Emergency Management).

The main purpose of this system is to assess consequences of nuclear accidents and to form a basis for making right decisions on countermeasures in order to reduce health effects and economical consequences. The system must therefore be able to make model predictions of dispersion and fallout of radioactive materials and to store, synthesize and present all available information and data during all phases of a nuclear accident. In order to assess consequences of a new accident the system must include all available data on the present radioactive contamination in the environment and in the food chains. The system will therefore serve as a tool in the daily work at the Norwegian Radiation Protection Authority and thus ensure knowledge of the system and efficient operation in an accident situation.

1. Introduction

When the Chernobyl accident happened in april 1986 there was no organization for coordinating nuclear emergency preparedness in Norway. Only a few laboratories maintained the expertise and the equipment to measure and analyze radioactivity in the air, in the environment and in the food chains. As a result of this the first phase after the Chernobyl accident was characterized by no clear distribution of responsibility, lack of a plan of organization and lack of equipment. A number of authorities did have duties and responsibility connected with radioactivity and accidents. The lack of planning meant that the affected agencies had to improvise their actions and only after a series of problems had arisen was the necessary coordination of efforts established. The large and legitimate demand from the public and the media for information represented a strain for which the system was unprepared, and made the work of the authorities more difficult.

In december 1986 The Norwegian Government appointed The Norwegian Emergency Organization (AVA). This organization should act as a coordinating body, should submit contingency plans and should make decisions or give advise on actions in case of an accident.

In the period from 1986 to 1993 systems for monitoring radioactive fallout and measuring equipment for mapping and measurements in the food chains were established.

In 1991 the Norwegian Government established an Inter-Ministerial working group to evaluate the existing emergency preparedness. This Inter-Ministerial working group presented their report to the Ministry of Health and Social Affairs in 1992. In order to make the emergency handling more effective in the early phases of nuclear accidents, changes in the existing organization and further development of the monitoring and measuring systems were suggested.

2. The emergency organization

A new emergency organization for nuclear accidents was appointed by the Government 15. april 1993. This emergency organization consists of:

* The Advisory Committee for Nuclear Accidents,
* The Crisis Committee for Nuclear Accidents,
* The Ministerial Coordination Committee,
* The regional emergency organizations.

The Advisory Committee consists of 18 authorities and organizations representing expertise and responsibility within fields of importance in handling a nuclear accident. In case of an accident they shall act as advisors to the Crisis Committee. During development and maintenance of the emergency preparedness the Advisory Committee will act as an advisory body for the Ministries and their Coordinating Committee.

The Crisis Committee consists of 6 authorities and organizations. In case of a nuclear accident, this committee has been given authority and responsibility to decide and order remedial actions in order to prevent or reduce radiological and economical consequences.

A secretariat for the Advisory Committee and the Crisis Committee has been appointed at the Norwegian Radiation Protection Authority (NRPA). The secretariat shall develop and maintain the emergency preparedness and act on practical matters on behalf of the emergency organization. The secretariat include the newly formed Emergency Unit on the Norwegian-Russian border at Svanhovd in the county of Finnmark. The Crisis Committee and the Advisory Committee will gather in the premises of the Norwegian Radiation Protection Authority during a nuclear accident.

In the Norwegian counties, local emergency organizations are established under the leadership of the chief administration officer.

3. The threat from installations and activities

As a part of the evaluation of emergency planning and the need for further developments, a survey of installations and activities representing a nuclear threat against Norway has been prepared. Both the location, the probability of a major accident and possible consequences for Norway were considered. The situation for Norway can be summarized as follows:

* The Norwegian need for electric power is supplied by hydroelectric power plants and Norway has no nuclear power plants. The Institute for Energy Technology in Norway own and operate two small research reactors, one with a thermal power of 2 MW and one with 25 MW thermal power.
* Nuclear power plants in our neighbouring countries must be taken into account as installations representing a threat against Norway.
* The nuclear power plants at the Kola peninsula and at Ringhals in Sweden are located approximately 250 km from the Norwegian border. The nuclear power plants in Sosnovyj Bor near St Petersburg and in Ignalina in Litauen are located approximately 800 km from Norway while installations at the east coast of United Kingdom are located 600 km from the south and west coast of our country. The two nuclear power plants in Finland must also be taken into account.
* Finnmark county has a common border with the Kola peninsula. The concentration of atomic weapons in this area together with the number of military installations for the Russian sea and air forces and the Kola nuclear power plant represent, in our opinion, a special threat

against our northern territories.
* The activity of nuclear powered military vessels, particularly submarines, in the northern parts of the Atlantic ocean and the Barents sea, and also the fleet of Russian ice breakers with their base in Murmansk, represents a threat against our northern territories and the Arctic marine environment.

The dominating nuclear threats against Norway given by priority are therefore:

* Accidents at foreign nuclear power plants,
* Accidents in nuclear powered vessels in the proximity of the Norwegian coast,
* Unintended detonation of atomic weapons during transportation, handling and storage,
* Reentry of nuclear powered space vessels and satellites,
* Accidents in Norwegian research reactors.

4. Systems for monitoring and measurements

The LORACON-system

The LORACON system (Local Radiation Control) consists of approximately 80 instrument sets located at 67 local laboratories for food control in Norwegian municipalities. The purpose of these instruments is to measure radioactivity in foodstuffs and samples from the environment.

Stationary monitoring stations

A network of 22 stationary stations for monitoring fallout in Norway is operated by the Norwegian Institute for Air Research (NILU). One station is located at the Kola peninsula half way between the Kola Nuclear Power Plant and the Norwegian border.

NILU has established a cooperation with seven of the LORACON stations. When the LORACON instruments are not used to measure radioactivity in food samples, the instruments are interfaced to form a part of the NILU stationary monitoring system.

Air sampling stations

Eight air sampling stations are located in Norway, including one on board the coastal steamer "M/S Midnattsol". Three of them are characterized as high volume air sampling stations. One of these are located at Svanhovd in the county of Finnmark approximately 1 km from the Russian border at the Kola peninsula.

Transportable dose rate meters

The civil defence groups at various locations in Norway have 176 transportable dose rate meters at their disposal for measurements of external dose rates in contaminated areas. They perform routine measurements by specific procedures at defined locations throughout Norway. In this way we gain experience with the radiation levels at these points. In case of a new fallout, it will be possible to analyze the amount at these locations. The civil defence groups and their instruments will also be used to map the fallout from an accident in contaminated areas.

5. A databased decision support system

The central emergency organization for nuclear accidents, the Crisis Committee and the Advisory Committee, are responsible for management of nuclear accident threatening or having consequences in Norway. The Crises Committee has been given extensive authority to decide and order remedial actions in order to prevent or reduce radiological and economical consequences in the Norwegian society.

The 18 organizations in the central emergency organization have information, data and operating responsibility for various measuring systems and equipment in order to evaluate an emergency situation. All these data and information must be available to the central emergency organization at their operation centre at the Norwegian Radiation Protection Authority. In addition these organizations have specified areas of responsibility during an emergency situation, all of which must be coordinated.

The daily maintenance and support of the emergency preparedness is carried out by the secretariat at the Norwegian Radiation protection Authority. The secretariat is responsible for maintaining a high level of readiness and availability of information required in accident situations. This implies that it must be a continuous activity to survey and monitor releases and the current radiation levels in Norway and in the neighbouring countries.

Considering the vast amount of information and data needed to keep an updated overview of a situation both during the daily surveillance work and during accident situations the need for an efficient information an retrieval system is evident. Accordingly, it has been decided to develop a computerized system for continuous monitoring and decision support in accident situation.

The main objectives of this system called NORMEM (Norwegian Major Emergency Management) is to:

* Assess consequences of nuclear accidents,
* Establish a basis for right decisions on countermeasures in order to reduce health effects and economical consequences.

The health effects considered are increased cancer risk for individuals and increased frequency of cancer in population groups or in the whole population. Only in special situation acute radiation effects must be considered.

To fulfil the main objectives, the NORMEM system must include functionalities covering the following areas of application:

* NORMEM shall contain tools for assessing the impact of real accidents to provide guidance and decision support for the emergency organization in accident situations.
* NORMEM shall contain tools for assessing hypothetical accidents to provide guidance and support for developing the emergency preparedness.
* NORMEM shall provide data and presentations necessary to support a continuous and updated public information and press service in an emergency situation.
* NORMEM shall function as an information collection an retrieval system for the NRPA, supporting the staff in maintaining an overview of the radiological situation in Norway and its environment, including the marine environment in the Arctic regions.
* NORMEM shall contain the means required to run in a training mode for use in preparedness exercises and in training of staff within the emergency organization.

The time phases of a nuclear accident are often divided into the early phase, the intermediate phase and the late phase. The decision support system must be available and give support to the emergency organization in the various phases.

We have found it convenient to describe the functions in NORMEM as administrative functions or technical functions.

Administrative functions

The functions described as administrative are those usually found in an emergency handbook, and includes:

* Description of the various parts of the emergency organization, its members and their responsibility within the organization.
* Description of procedures for alarming and mobilization of all parts of the emergency organization.
* Contact points within the Ministries and other relevant organizations in Norway.
* Descriptions of other Nordic emergency organizations with contact points and information on communication systems.
* Description of international organizations to be contacted and how.
* Descriptions of bilateral and international agreements and the requirements and procedures to fulfil these agreements.
* Descriptions of all resources available to the emergency organization, described as what, where, how many, responsible person and contact point.
* Means for receiving, logging, management and storage of all messages received or transmitted.

Technical functions

As a part of the basis for management of a nuclear accident we must have:

* Information on fixed installations containing radioactive sources and examples of expected source terms in case of accidents. This information shall include knowledge of incidents and accidents for these sources. These sources are nuclear power plants and other reactors, reprocessing plants, stocks and dumping areas of radioactive waste, nuclear weapon test sites and concentrations of atomic weapons if possible.
* Information on movable installations containing radioactive sources. This includes reactor powered military vessels i.e surface vessels and submarines, the fleet of Russian icebreakers and nuclear powered satellites.
* Data on the present levels of contamination in the air, at the ground, in water, in the environment (vegetation, animals), in the food chains and in foodstuffs. These data can be used during the regular work on radiation protection at the Norwegian Radiation Protection Authority and in cooperation with other institutions, but must also be available in order to assess the consequences of a new accident.
* Data on the external exposure rates from natural sources and from the present contamination at the ground and in the environment.

In the acute phase of a nuclear accident we must have:

* Meteorological data and models for predicting transport of radioactive materials from a given source term in air and in water.
* Models for predicting air, ground and water contamination levels given the source term, meteorological conditions and aquatic conditions.
* Models for predicting the radiological impact of radioactive substances and their migration in the environment and the food chains.

These models are tools for predicting consequences and make decisions on countermeasures in the early and intermediate phases of a nuclear accident when little is known about the situation and how it will evolve.

In the intermediate and late phases of a nuclear accident:

* Information and data from all kinds of measurements made during and after an accident shall be available. This includes data on dose rates and contamination levels in air, at the ground, in water,

vegetation, animals, the food chains and in foodstuffs. All considerations of consequences must be based on this total amount of information. It must therefore be possible to register and to store a vast amount of data in a systematic way in the NORMEM system.

* Necessary functions for handling, synthesizing and displaying information and data on digital maps in graphs and charts. Presentation of information and data in a comprehensive way either as predictions from model calculations or from measurements must be possible for assessing the evolvement of the situation and for assessing the present situation all the time.

* Models and algorithms for estimation of doses to individuals and population groups either from predictions of contamination levels or from measurements of dose rates and contamination levels. Radiation doses to individuals and to population groups must be known in order to assess the health effects and also as a basis for introducing countermeasures.

* Models and algorithms for calculating short term and long term consequences from predicted contamination levels or from measurements.

* Models and algorithms for calculating the cost-effectiveness, optimization and adverted doses for countermeasures. The main rule in radiation protection is that countermeasures shall be justified by producing a net benefit for individuals and the society. The reduction in detriment resulting from the reduction in dose should be sufficient to justify the harm and costs, including social costs, of the countermeasure. In addition countermeasures shall be optimized in form, scale and duration.

* Means of assessing long term impact taking into account all countermeasures and consequences on the Norwegian territory and for the Norwegian population. Consequences are increased frequency of cancer and economical and social costs.

5. Software and hardware tools

The basic software tools behind NORMEM will be a data base management system (DBMS), a user interface management system (UIMS) and a geographical information system (GIS). The data base will be used to store heterogenous information in the NORMEM system. Institute for Energy Technology (IFE) will incorporate their UIMS tool PICASSO in NORMEM to give access to and to present data and information stored in the data base. A GIS-tool will be used for displaying information and data from the data base on digital maps. The Norwegian Radiation Protection Authority has already a SYBASE SQL server available for the system.

The NORMEM system will be developed to run on a HP 9000/735 work station under UNIX located at the Norwegian Radiation Protection Authority.

DEVELOPMENT OF THE EMERGENCY RESPONSE SUPPORT SYSTEM IN JAPAN

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ABSTRACT

The Emergency Response Support System (ERSS) is set up to support the activity of the Ministry of International Trade and Industry (MITI) in case of emergency in a commercial nuclear power plant in Japan. The ERSS provides MITI with effective technical information by linking the MITI computer system with those in nuclear power plants. The development of the ERSS started in FY 1987 and is scheduled to end in FY 1995. The ERSS consists of five subsystems: the Information Processing System, the Diagnosis/Prediction System, the Analytical Prediction System, the Large Display System and the Transmitted Plant Parameters Simulation System. In the prototype all subsystems are installed in the computer room of Nuclear Power Engineering Corporation (NUPEC) whereas in the practical system the Information Processing System (Information Collection Module) and the Large Display System are installed in the MITI Decision Making Room. The other difference between the prototype and the practical system is that the simulated data are produced by the Transmitted Plant Parameters Simulation System and are used in the former in stead of the real plant information used in the latter.

INTRODUCTION

After the accident occurred at Chernobyl in April 1986, the Nuclear Safety Commission of Japan pointed out the importance of improving the practicality of various emergency measures in its investigative report on the accident published in May 1987. In response, the Ministry of International Trade and Industry (MITI) studied the action that the government of Japan, local self-governing bodies, and utility companies should take in an emergency; the roles of MITI and utilities and their specific actions; judgment of emergency situations and their classification; and the Emergency Response Support System (ERSS).

The role of MITI in an emergency situation at a nuclear power station is to grasp the plant situation accurately, to predict if the situation could become worse or not, and to evaluate the effect of radioactive material released on the environment around the plant site. The objective of the ERSS is to supply information relating to the above items to MITI personnel and to support their activity during an emergency situation of a nuclear power plant.

On the basis of the studies MITI entrusted the Nuclear Power Engineering Corporation (NUPEC) with the development of ERSS. The NUPEC decided to adopt a two-steps development plan: the first step (FY 1987 - FY 1992) is devoted to develop the ERSS prototype and the second (FY 1993 - FY 1995) to attain its practicality.

In the design of the ERSS the system is presumed to be activated in the event of "the design basis accidents (DBA)" (e.g., loss of coolant accident), "situations more serious than DBA" (e.g., severe accidents), etc. at a commercial nuclear power plant (light water reactor type) in Japan. According to the decision of the utility, plant parameters of an affected plant are transmitted to the ERSS from the plant site in the case of an emergency.

In the succeeding parts of this paper the explanation of the practical system is first given in the aspect of its completion and then the prototype is described from the view point of the differences between two systems.

CONSTITUTION OF THE ERSS

Figure 1 shows the fundamental constitution of the ERSS. The main processing part of the ERSS consists of five subsystems: the Information Processing System, the Diagnosis/Prediction System, the Analytical Prediction System, the Large Display

System and the Transmitted Plant Parameters Simulation System. In the NUPEC Operation Room are installed the main processing parts with the exception of the Information Processing System (Information Collection Module) and the Large Display System, which are installed in the MITI Decision Making Room.

The plant parameters are first transmitted to MITI and then transferred to NUPEC. The information from the plant is automatically displayed on the Large Display System before it is processed at the NUPEC Operation Room. Besides the above on-line information some information will be informed through off-line devices (telephone, facsimile, etc.). These are manually input to the ERSS at the Decision Making Room.

Main results obtained by the Diagnosis/Prediction System and the Analytical Prediction System are shown on the Large Display System through the Information Processing System. If required, the detailed results of these subsystems can be seen at the Decision Making Room through engineering workstations (EWS).

The Transmitted Plant Parameters Simulation System is installed for the purpose of emergency drills.

THE INFORMATION PROCESSING SYSTEM

The Information Processing System is divided into two modules: Information Collection Module and Information Control Module. The former module is installed in the MITI Decision Making Room and is in charge of functions such as data acceptance, transmission and archives. The latter module is in the NUPEC Operation Room and is in charge of managing other subsystems.

The numbers of plant parameters transmitted from a plant are about 70 for BWR and 100 for PWR. These parameters are selected from the following points of view:

- Usefulness of parameters in specified accident sequences which are studied in the probabilistic safety assessment (PSA),
- Requirements from the Diagnosis/Prediction System and the Analytical Prediction System.

The plant parameters are transmitted once per minute through the Packet Switched Network of the Nippon Telegraph and Telephone Corp. (NTT).

THE DIAGNOSIS/PREDICTION SYSTEM

Constitution of the Diagnosis/Prediction System

The Diagnosis/Prediction System is an artificial intelligence (AI) system which is constructed on a real-time expert shell "G2". As shown in Figure 2, two inference systems are included in the subsystem. The #1 inference system is operated in real time mode immediately after the plant parameters are transmitted from the plant site. The #2 inference system is usually in standby mode and is operated in catch-up mode when off-line data are manually input. The #2 system is also used for executing the "what-if-study".

The #2 inference system can run faster than the #1 inference system. When the #2 system catches up with the #1 system the processed data in the #2 system are transferred after synchronization is established.

Functions of the Diagnosis/Prediction System

The objective of the Diagnosis/Prediction System is to offer information on the present plant situation and the prediction of the future plant state by applying the artificial intelligence technology.

Because an accident scenario cannot be known for an unprecedented accident the symptom-based inference is adopted first and the scenario-based inference is employed as an auxiliary mean. The following 13 functions are the basic functions of the Diagnosis/Prediction System:

((Event Identification))

- Initial Event Judgment
  The cause of an accident is assumed and identified. Clarifying the cause deepens the understanding of the accident situation at hand and increases confidence in determining countermeasures.
- Accident Scenario Identification
  In addition to the initial event, the accident scenario is identified in the real-time way.

((Plant Situation Determination))

- State of Safety Functions Determination
  The status of the following four safety functions is determined: reactivity control, core cooling, decay heat removal, and containment vessel soundness.
- Radioactivity Barrier State Comprehension

The soundness of the core, reactor pressure vessel, and containment vessel is determined from the point of view of radioactivity barriers.

((Emergency Situation Judgment))

- Convergence/Progress of Accident Determination

  Information is provided for determining whether the accident will be put down or expanded.
- Emergency Action Level Judgment

  Information is provided for determining the level of the emergency (classified into four levels).

((Countermeasure Determination))

- Judgment of Operations Influencing Radioactive Release

  The feasibility of plant operations which lead to radioactivity release is determined.
- Judgment of Necessity to Notify Related Agencies of the Accident

  Information is provided for judging whether related agencies should be consulted or not.

((Plant State Prediction))

- Prediction of Accident Progress Based on the Knowledge Data Base

  On the basis of the knowledge data base on plant behavior, qualitative and quantitative information is provided for predicting whether the accident will cease or escalate.
- Prediction of Accident Progress Based on Simple Simulation

  Prediction capability of the ERSS is reinforced by adding a simplified physical model analysis to the AI process.

((Radioactive Material Prediction))

- Prediction of Released Amount of Radioactive Material

  Quantity of released radioactivity is estimated by using the data of the core fission product inventory and its fractions.
- Prediction of Dose Rate around the Plant Site

  The quantity of the released fission products on the surrounding area is evaluated by using a simple exposure-effect evaluation code.

((Emergency Situation Transition))

- Prediction of Changes in an Emergency Situation

  Transition in the emergency action level is predicted from the results of the plant state prediction.

Knowledge Data Base

The functions of the subsystem can be attained by comparing the transmitted plant parameters with the previously collected knowledge-based data, which are mainly extracted from the "PSA Levels 1 and 2" studies.

For this purpose many kinds of severe accidents were analyzed by the MAAP (Modular Accident Analysis Program) code. The comparison of these analyses with those by other severe accident analysis codes (e.g., MELCOR, THALES/ART, etc.) shows that the MAAP analyses are generally acceptable to the ERSS.

THE ANALYTICAL PREDICTION SYSTEM

The purpose of the Analytical Prediction System (APS) is to supplement the prediction functions of the Diagnosis/ Prediction System. The main part of APS consists of a sophisticated version of the MAAP code and can be started at any moment of the transition of the accident by inputting the plant parameters transferred from the plant (Initiation Mode).

In a short duration after the start of the APS its output is compared with the plant parameters in the duration. If a considerable deviation is detected, the start condition of the APS is modified by inputting the latest plant parameters at the end of the duration and/or by modifying a system parameter (e.g., a size of breakage in the case of LOCA) (Tracking Mode). When the deviation is regarded permissible the APS is ready for the prediction and can be run at the request of users (Prediction Mode).

The following is information provided by the APS which is considered to be useful for precise comprehension of the plant situation.

((Event Information))

- Possibility of core exposure and its predicted time
- Possibility of hydrogen generation and its predicted time
- Possibility of change in core shape and its predicted time
- Possibility of reactor vessel breakage and its predicted time
- Possibility of containment vessel breakage and its predicted time

((Quantitative Information))

- Coolant pressure, temperature, etc.
- Core cooling condition (amount of coolant, fuel temperature, etc.)
- Core damage condition (Zr-water reaction, fuel

melting, etc.)
- Debris cooling condition (water quantity in lower plenum, debris temperature, etc.)
- Explosion/deflagration (hydrogen generation, concrete reaction, etc.)
- Effect on environment (fission product distribution in plant, fission product release to environment).

THE LARGE DISPLAY SYSTEM

The Large Display System in the MITI Decision Making Room consists of four 58" display units (arranged in 2x2) and peripheral equipment. Figure 3 shows an example of the screen layout for a BWR plant. A similar layout is also prepared for PWR. The right-hand side of the screen shows plant site information whereas the left-hand side shows diagnosis/prediction information.

The name of an affected plant and its scram time are indicated in the upper part of the upper right-hand side quarter. The plant system status (e.g., remarkable phenomena and machinery status in the plant) is shown in the second part and the environmental parameters (e.g., meteorological parameters and readings of radiation monitoring posts) are shown in the third part. The lower right-hand side quarter is a changeable window and shows main plant parameters and their trend graphs by menu selection. The menu buttons appear at the bottom of the quarter.

The initiating event, accident scenario and emergency action level are estimated by the Diagnosis/Prediction System and indicated at the top of the upper left-hand side quarter. The remaining part of the quarter shows the inference results of the radioactivity barrier and the status of safety functions. Messages relating to the prediction of accident progress are sequentially shown in this quarter. The lower left-hand side quarter is a changeable window and shows information from the Diagnosis/Prediction System and the Analytical Prediction System. In Figure 3 the quarter shows a network expression for predicting accident progression. The menu buttons appear at the lower part of the quarter. The bottom of the quarter is a window relating messages on the ERSS computer system status.

THE TRANSMITTED PLANT PARAMETERS SIMULATION SYSTEM

The Transmitted Plant Parameters Simulation System is installed mainly for the purpose of accident drills. The subsystem simulates the plant parameters which will be transmitted from a plant in a real situation. The main part of the simulated data is produced by converting the MAAP results. Some of the simulated data (e.g., meteorological data) are newly created and added in order to complete the simulation.

The frequency of producing the simulated data is one minute by the analogy of the frequency of transmitting the actual plant parameters.

THE ERSS PROTOTYPE

As explained before, the prototype of the ERSS has been completed in FY 1992. Almost all functions of the practical system are realized in the prototype. The major difference between the practical system and the prototype is that the former is separately installed in MITI and NUPEC whereas the latter is only in NUPEC. The other differences are as follows.

- In stead of actual plants the following typical BWR and PWR plants are considered as reference plants in the prototype.

  BWR: 800MWe MARK-I BWR-4 plant
  PWR: 1100MWe improved and standardized 4-loop plant

  These plants were selected because of the abundant PSA data available in them.
- In stead of actual plant parameters the simulated data produced by The Transmitted Plant Parameters Simulation System are used.
- The numbers of simulated plant parameters for the typical BWR and PWR plants are:

BWR	on-line	62
	off-line	6
PWR	on-line	94
	off-line	7

- The Large Display System is simulated by using four 19" display units arranged in 2x2.

ACKNOWLEDGMENT

This work was carried out under the auspices of the Ministry of International Trade and Industry.

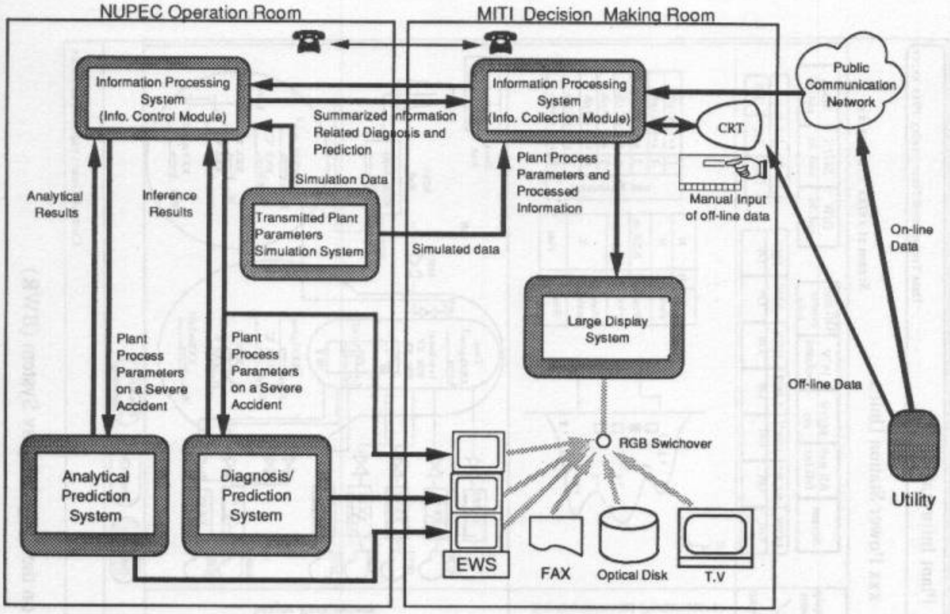

Figure 1. Constitution of the ERSS Practical System

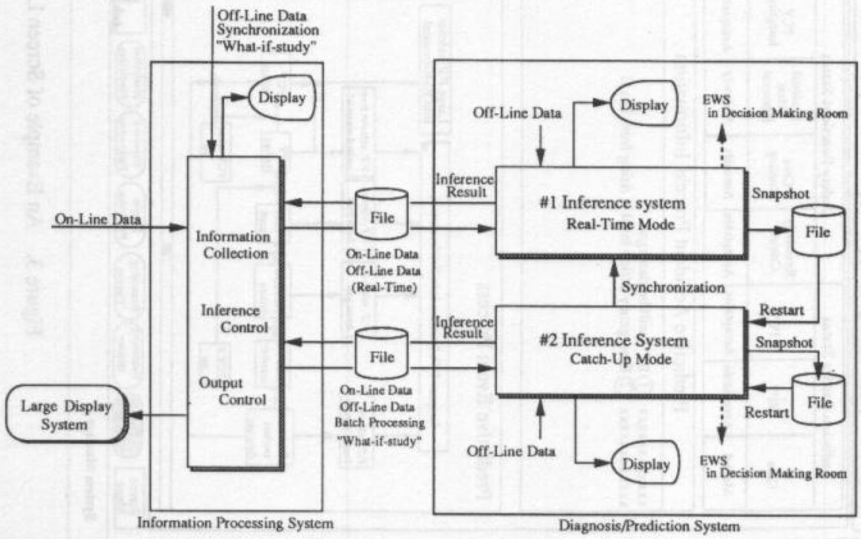

Figure 2. Two Inference Systems in the Diagnosis/Prediction System

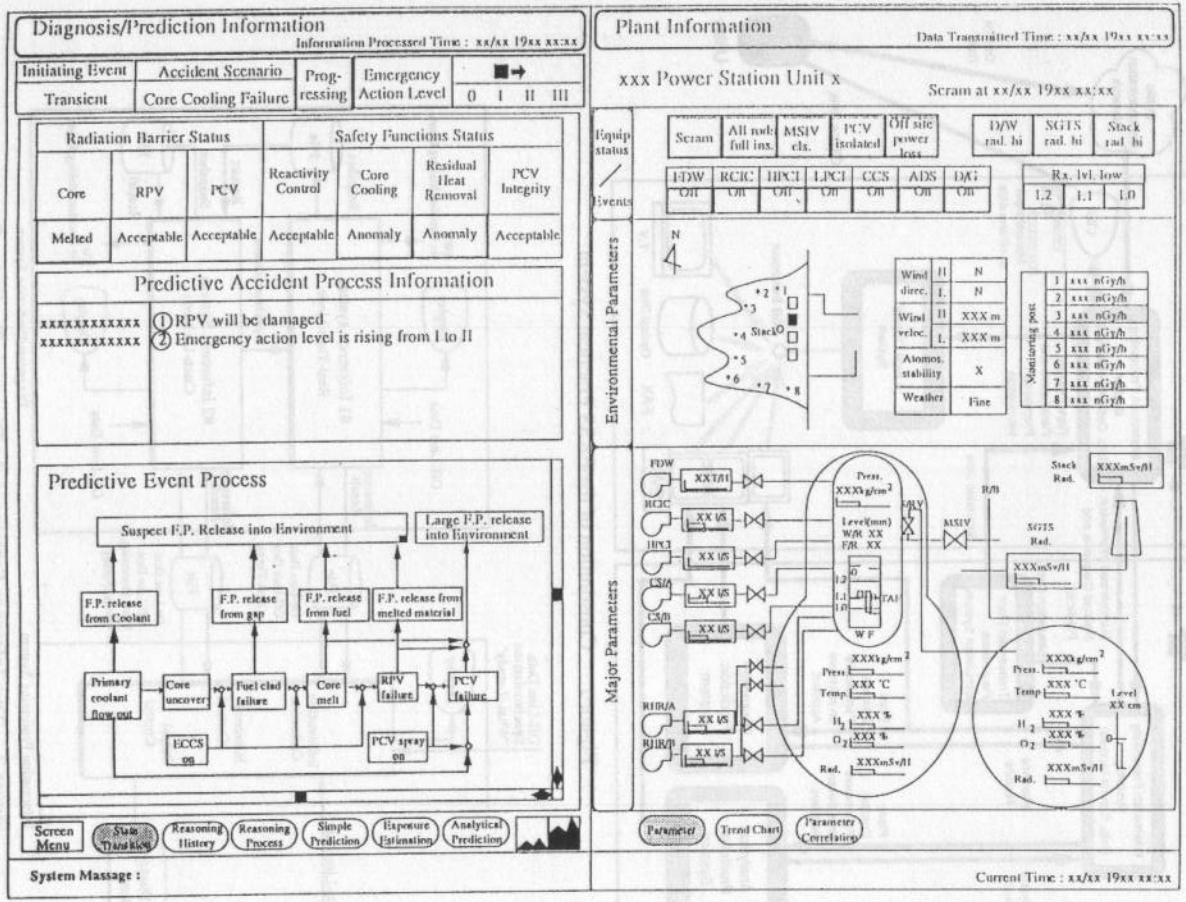

Figure 3. An Example of Screen Layout on the Large Display System (BWR)

GIS APPLICATION FOR CIVIL PROTECTION AND RESCUE IN THE CASE OF A NUCLEAR POWER PLANT EVENT IN KRŠKO, SLOVENIA

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ABSTRACT

GIS Krško was designed to provide emergency planning for on-site and off-site population in Slovenia, based on potential hazard impacts identified in the facility emergency plan [IAEA, 1986]. The data Base Management System (DBMS) consists of specific and global information levels, i.e. for operational tactical needs. Radiological monitoring includes all the meteorological stations, sampling sites for soil, air, atmosphere and food, iodine and aerosol pumps and the evaluation of critical sectors. The Gauss model simulates the concentration gradients of a nuclear cloud (ηS/h) in the radius of 25 km off-site of the NPP Krško and is calibrated with on-line measured data. The simulation model approach considers fundamental physical and operational characteristics of the evacuation network and the optimisation evacuation route. For the purposes of Protection and Rescue the following data are determined: evacuation centres, shelters, schools, industrial buildings, land use, farms, infrastructure, communications of emergency warning system, civil protection and fire brigade units, rescue equipment, medical aid and institutions, hydrology, digital terrain model and register of the territorial units of Slovenian state territory. The specific data base is graphically transposed using digitalisation of maps on the scale of 1:25000 for 25 km radius off-site of NPP and in-site maps 1:5000 for the radius of 3 km. The global data base for the whole country uses a map on the scale of 1:250000 for the purposes of the structures of the Civil Protection and other rescue units, both alarm and national monitoring systems. GIS is furthermore a useful tool in developing drill and exercise scenarios. In addition, the database, once established, can be used to assess the merits of various management measures aimed at developing an effective, site-specific evacuation plan.

1. INTRODUCTION

The use of dangerous materials in various fields of industry, power production, medicine and research has been increasing over the past [Martinčič, 1992] [1]. In the last two decades in Slovenia, a global safety and protection system has been established consisting of three major parts:

- legislation
- safety and protection system for the normal operation of facilities or the use of dangerous materials and
- emergency planning and readiness for nuclear or any other ecological accident.

[1]Member of Slovenian Committee of Large Dams
[2]Expert Committee for Nuclear Safety of Slovenia

The System for Protection and Rescue is based on the responsibilities of the state and local communities to organise and execute measures and activities for removing the danger of natural and other disasters and preventing as well as reducing the consequences. It is also based on the responsibilities of enterprises, institutions and other organisations to organise and execute essential measures for the protection of employees and property within the framework of their activities. The government is primarily concerned with the systems arrangement of the fields of protection and rescue, research work, execution of national security programmes, organisation of certain rescue units and services intended for assistance to local communities [Ušeničnik, 1993][2]. In 1987, the Republic Civil Defence Headquarters established highly professional emergency units, which represent one component of the global safety and protection system. The Ecological Laboratory and Mobile Unit (ELMU) established at the J. Stefan, Institute within the UNDP project has been recognized as one such unit. Its main objective is detection and determination of accidental pollution of the environment with radioactive substances and specific chemical or biological compounds giving professional recommendations to authorities and organisations responsible for the implementation of protective measures as shown in fig. 1 [NUREG, 1980][3].

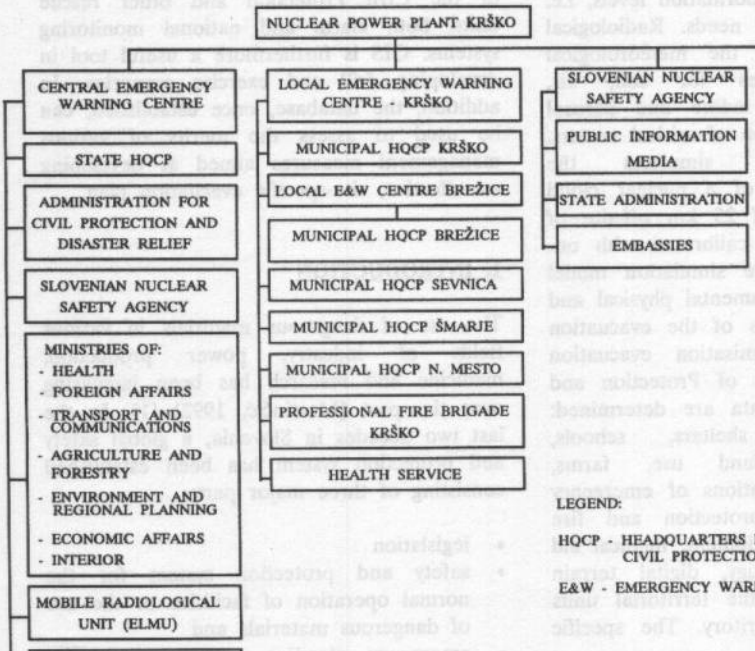

Figure 1: Organisation for directing general emergency planning at NPP event in Krško.

2. EMERGENCY PLANNING AT NPP

Taking into account the recommendations for improvement of operational safety and maintenance in NPP operation, several models are derived with a certain probability of occurrence of an unusual event [Gaertner, 1993][4]. The concept of risk assessment is converted into GIS programming by collecting, combining and using numerical (descriptive) and graphical spatial data. The geodetic base is composed of geodetic codes, topography elements, land mapping, hydrology, infrastructure, terrain, land use and register of local communities and national administration. All data layers are derived from the 1:5000 and 1:25000 scale survey sheets for the purposes of detailed specific database. An overview of the global data base is given from 1:250000 scale maps. A detailed description of GIS database organisational structure is given in figure 2 [Žura, 1993][5].

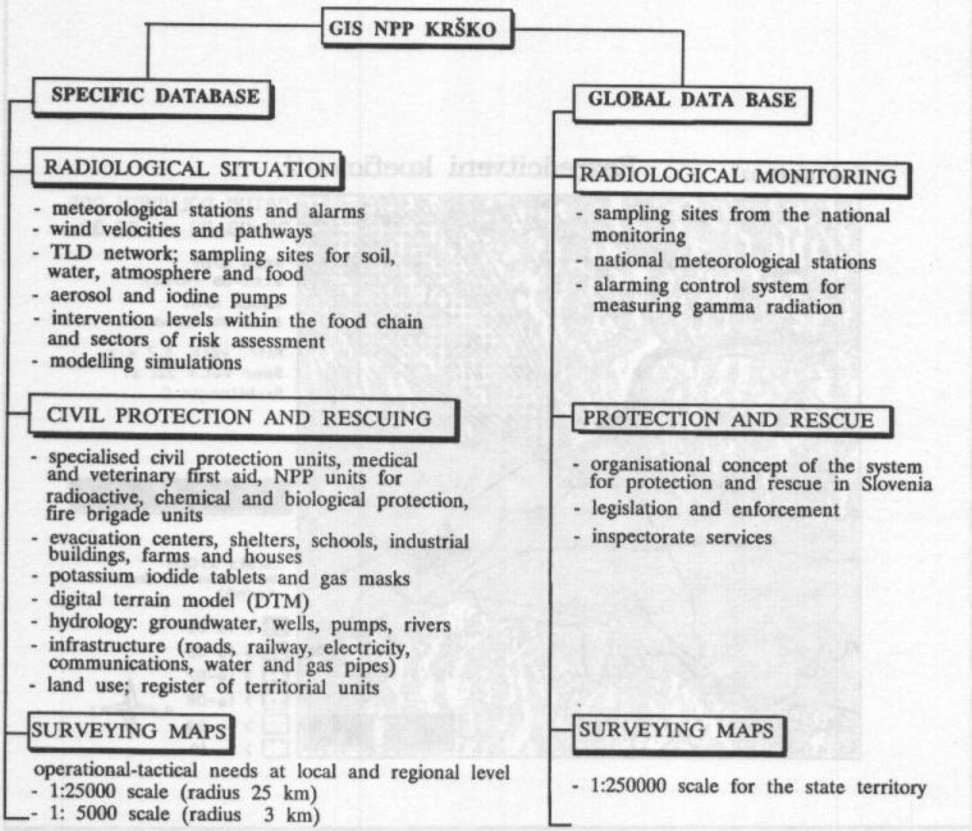

Figure 2: Database structure for GIS application for emergency planning at NPP Krško.

3. RADIOLOGICAL MONITORING

Integrated PUFF programme has the ability to assess real-time and forecast dispersion at un-steady state conditions, also considering spatial and time variability of wind. Radiological dose trajectories are determined for both 10 km and 25 km exposure pathway emergency planning zone. INPUFF model can be used to provide an immediate assessment of initial dose estimates, based on plant-specific radiological and meteorological parameters. Dilution coefficients at 30-minute reporting intervals (fig. 3) show deposition rates and SW direction of the Gaussian cloud. Dilution gradients vary between 10^{-5} to 10^{-10} s/m^3.

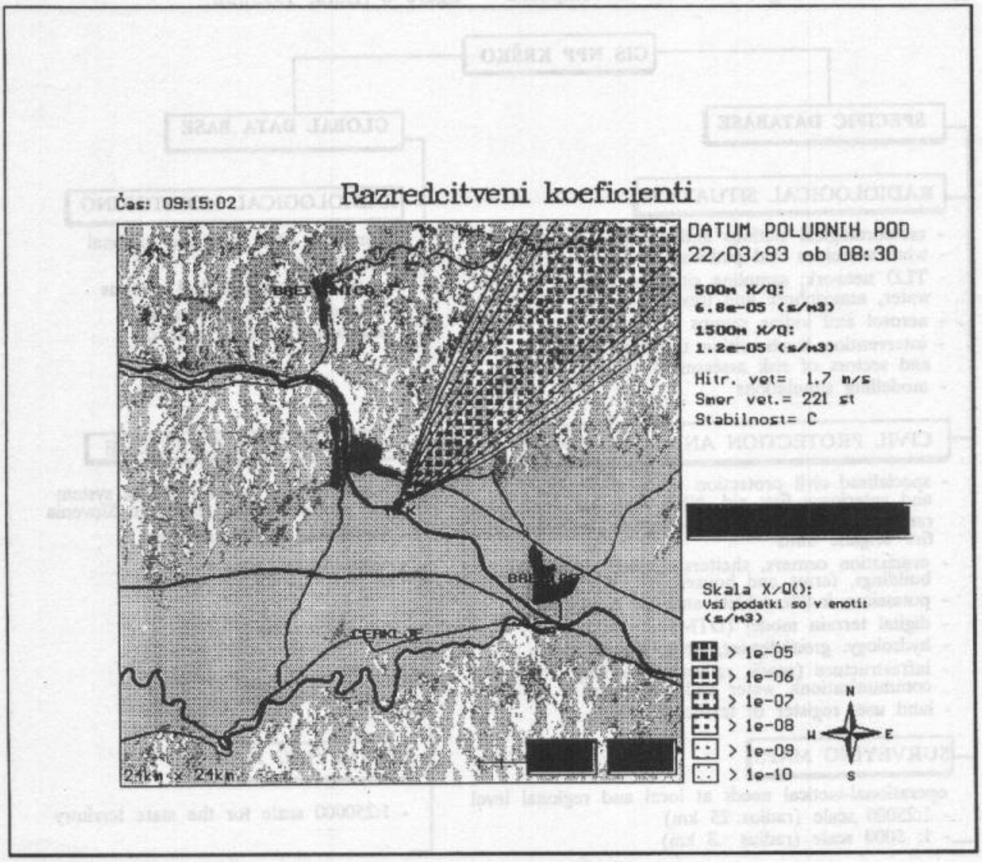

Figure 3.:Radiological monitoring off-site of NPP Krško for an area of 24 km x 24 km (Courtesy of the Agency for Civil Protection and Disaster Relief, 1993).

4 CONCLUSIONS

Physical planning is implemented with spatial and descriptive data for evacuation procedures. The GIS multiple scenario analyses achieved with the computer evacuation simulation model, include population and transportation network data developed through demographic and transportation studies (fig. 4). The procedures are integrated with existing emergency response procedures and contain responsibilities and decision-making checklist format. The structural plan of civil protection and rescue in the case of a Nuclear Power Plant Event is designed in a compatible manner. It can be easily extended for the purposes of emergency planning for other natural disasters in Slovenia. Some advanced techniques are implemented in the project like digital terrain model off-site of the NPP Krško, to determine preferential wind pathways in the surrounding valley of the Sava river (fig. 5).

Hopefully this article will contribute to the international decade for natural disaster reduction action and other relevant efforts elsewhere taking into consideration prevention measures.

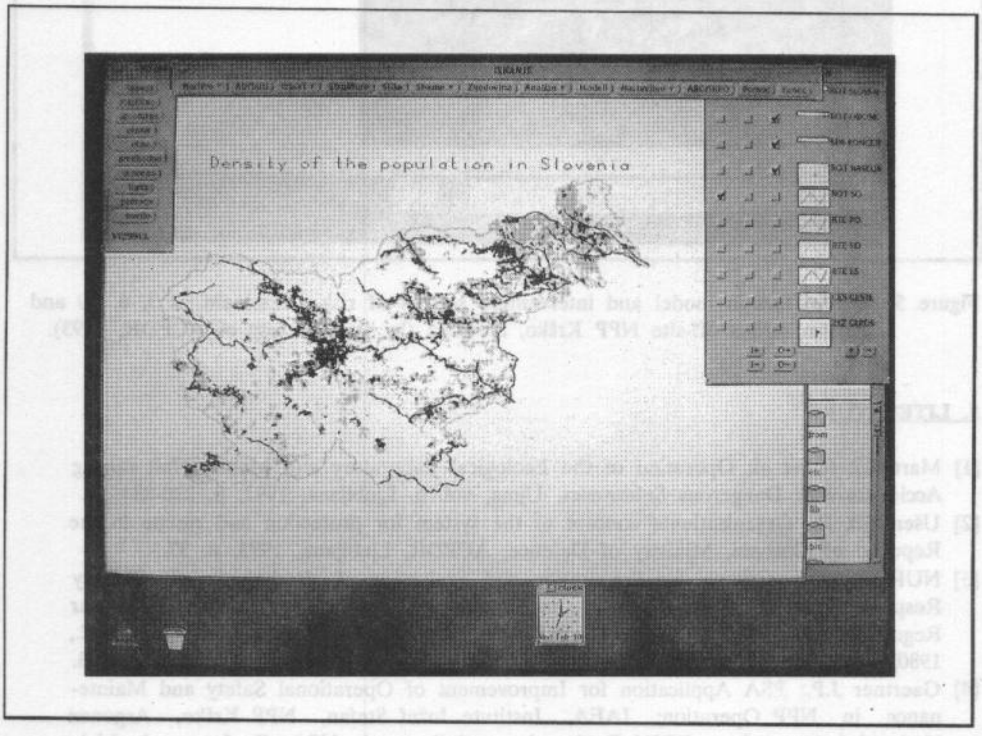

Figure 4.: Demographic distribution of the Slovenian population, ranking from 25, 50, 100 or over 100 citizens/km^2. Major rivers are in the background (By the courtesy of ACPDR, 1993).

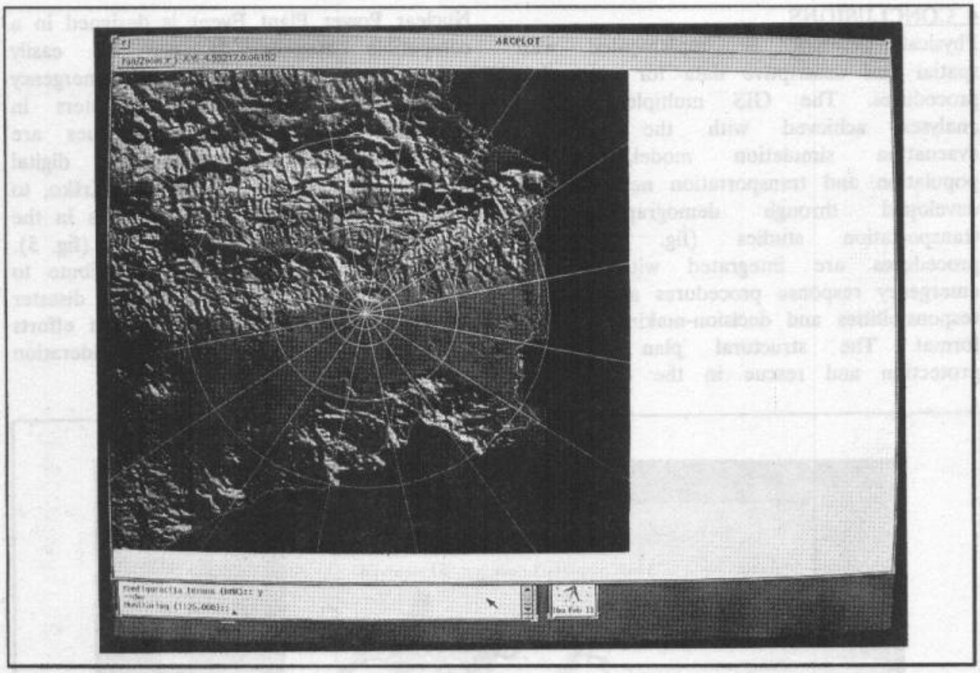

Figure 5.: Digital terrain model and intervention sectors of risk assessment at 3, 6, 10 and 25 km radius off-site NPP Krško, Slovenia (by the courtesy of ACPDR, 1993).

5. LITERATURE

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STANDARDS FOR EMERGENCY MANAGEMENT SYSTEMS

Integration of Emergency Management Information Systems: Towards a Common Reference Model

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1 Introduction

The goal of this paper is to propose to the international Emergency Management community a framework for carrying out a coordinated effort of standardization of information systems used in the process of managing emergencies. *Integration* of emergency-related *information* of different sources will be the crucial factor in the near and longer-term future in achieving effective, coordinated management of a major crisis. The authors demonstrate why integration of information is indeed such an important issue in Emergency Management. They then go on to analyze the integration issues specifically related to Emergency Management. A correlation is then drawn between EM Integration and "classical" integration issues in information systems. Based on available integration technology addressing these issues, the authors then present a proposal for a common Emergency Management Integration Reference Model (EMIRM) which defines the services and tools necessary to achieve integration of Emergency Management information systems. The advantage of developing such a Reference Model is believed to be a significant contribution to attaining standardization in support for Emergency Management.

2 The role of information in Emergency Management

When emergencies occur they are generally tackled on the *ad-hoc* basis of experts exercising relevant knowledge *in situ*. Expert knowledge is usually enhanced in this complex task by pre-established procedures which contribute valuable "structure" to a chaotic situation. Nevertheless, the very nature of emergency procedures would make unlikely the use of fully automated operational emergency procedures. Indeed, emergency procedures can only be of limited help since they are predefined i.e., static, while no two emergencies are precisely the same. That is why the decision-maker, in charge of an emergency situation, in fact relies on the provision of up-to-date *information* related to the various aspects of the emergency in order to effectively tackle it. The importance of information in Emergency Management was demonstrated at a recent panel discussion [1], where experienced state emergency managers expressed the opinion that coupling Geographic Information Systems (GIS) and mobile means of communication will constitute the most significant enhancement to their practice. "Establish a modern communications and information resources management system" has indeed been one of the recommendations of the National Academy of Public Administration in recent survey carried out on behalf of the U.S. Congress and FEMA on the future of Emergency Management in the U.S.A [2].

3 Integration of information in Emergency Management

The result of successful integration is the perception, by the user, of coherence and consistency between the different elements of information at his disposal for carrying out a given task. Integration is of interest to decision-makers in Emergency Management since it reduces the overwhelming complexity of the situation at hand by creating logical, operational links between otherwise disparate elements.

Thus, for example, it is useful to know during an emergency both the meteorological conditions on-site as well as the situation of traffic on nearby roads. Yet, it is of infinitely greater use to decision-makers to be able to localize on screen the occurrence of heavy rain *shown in direct relation* to the highway adjacent to the site of the emergency at hand.

4 The need for integration in Emergency Management

Integration in the case of Emergency Management should create for the user a single, unified working environment within which s/he can carry out all relevant activities.

Emergency Management integration therefore addresses several related user needs:

- Integration of **information** from various sources, of heterogeneous formats and conveying different levels of meaning in order to provide the decision-maker with a comprehensive and coherent view of the emergency situation.
- Integration of, and cooperation between different computer-based **tools** used to deal with various aspects of Emergency Management e.g., evacuation, message exchange, simulation.
- Integration of the different aspects making up the **working environment** of the emergency manager into a single, unified command and control console e.g., telephone, computer, fax.
- Integration between the different tasks, carried out by a variety of actors, making up the overall complex **process** of managing an emergency e.g., abatement, evacuation, communication.

5 Information system issues of Emergency Management Integration

The above-mentioned, specific integration needs of emergency managers can in fact be addressed through the use of "classic" *integration techniques* commonly utilized in the development of complex information systems,respectively: **data, control, presentation,** and *process* integration.

Let us therefore consider further some of the specific needs of Emergency Management in terms of information system integration.

Data integration

- During an emergency there is a need to use in a tightly cooperative manner data which is integrated *exclusively* at the time of emergency e.g., information about traffic, hospital capacity and meteorological conditions. This impromptu nature of integration is virtually a "guarantee" that data will not integrate smoothly (recently updated formats, new limits on values etc.)
- Many sources of data, useful in an emergency, are confidential to some extent. Total owner control over information should therefore be guaranteed when making such data available to other systems.
- Many sources of data are set up with only a single software tool to exploit them in mind. Other software systems may thus find these data inflexible to exploit. A mechanism is therefore needed which enables the sharing of data through existing, independent tools.
- Very little, if any time is available to effectively set up data sharing from the moment an emergency is declared to the moment integrated data are expected to be made available. Data-sharing mechanisms must therefore be flexible enough to allow such *ad hoc* operations.
- Since different sources of data are the property of different organizations, they are almost inevitably physically distributed. Significant support for data distribution should be provided.
- Geographic data are by far the most requested type of information during an emergency [3]. Yet almost every single GIS product has its own propriety data management system. Several bodies are working on the standardization of GIS data-exchange [4]). A recognized, international GIS-data standard is therefore needed.

Control integration

- Emergency managers are, in the current situation, mostly using as decision support various stand-alone software tools developed by different vendors with no *a priori* intention in mind of cooperating with other systems. It is necessary to provide support for cooperation between systems at the software tool level on a variety of hardware and system-level software platforms.

Presentation integration

- Emergency management deals with very complex situations whence a profusion of information to be communicated to decision-makers. Presentation must therefore act at once as an integrator and as a filter, integrating only the most pertinent information and avoiding accumulation of integrated yet, at the same time, unexploitable information.

- During an emergency the decision-maker is literally flooded with information. It is therefore crucial that every bit of information presented to him/her is visually presented together with related information in a manner whereby the simultaneous presentation of different bits of information enhances their meaning for the user.

Process integration

- Emergency management is characterized by rigorous, pre-established procedures which define precise roles for people at different levels of the hierarchy whereas actions on-site are taken by *de facto*-autonomous agents in an order dictated to a great extent by the evolution of the emergency.

- Procedures are necessarily devised per *type* of emergency while each single emergency has its own very important discrepancies from the general "rule" or "order of events". Thus many of the most effective actions during an emergency are taken on the basis of intuition alone without reference to procedures and in a manner which may be difficult to structure.

It is therefore necessary to provide Emergency Management support which implements existing plans of action while leaving them flexible enough to take into account the effect of related events as they occur.

- Many actors with different skills and responsibilities are involved in managing an emergency. Moreover, the emergency is the first occasion for most of them to collaborate in an operational manner. There is therefore a need to provide Emergency Management support which is highly adaptable to the structure of the organization tackling the emergency.

We can thus characterize the need for integration of information necessary for Emergency Management decision support as:

- bringing together very heterogeneous, independent system elements,
- requiring short delay for its deployment,
- addressing a naturally unstructured work process,
- requiring a unified approach for the presentation of its results.

6 A common Reference Model as a means for achieving integration

Having demonstrated the need for integration of information related to the different aspects of Emergency Management we now need to propose a pragmatic approach for actually achieving it. The proposed approach consists of defining *a common Reference Model for Integrated Emergency Management - EMIRM*. The EMIRM defines:

- The information services which should be proposed to emergency managers.

- How these services are *used* in a cooperative manner i.e., what are the expected, standard exchanges between these services.

- How do these services cooperate on a *system level* to achieve a level of service satisfactory to the user.

These aspects are defined on a functional level which can then be implemented in any of several possible manners, on different platforms.

The EMIRM is *not* a description of a single system and its graphical representation (see figure 1) in no way constitutes a system architecture. The EMIRM should be considered on a *functional level.* To simplify, the EMIRM can be viewed as an elaborate, standard checklist which enumerates useful Emergency Management services and functions while describing how they can be used in a cooperative manner within an integrated information system. The cooperation between tools is defined from both a user and systems point of view. The EMIRM therefore provides:

- Principles, *at the functional level,* for developing Emergency Management information systems.
- Guidelines for evaluating existing systems according to the same criteria.

How should the EMIRM be used?

The EMIRM can be used in several manners:

- **Tool developers/vendors** can evaluate how the value of their specific Emergency Management tools can be enhanced through its utilisation in relation with tools and services addressing other aspects of Emergency Management.
- **Application developers** can examine whether their system addresses all the relevant issues required for achieving integration and how it is positioned in relation to other possible functions not yet provided by their system.
- **End users** (emergency managers) can obtain a wide, global view of possible services and functions and use the EMIRM to evaluate proposed tools and systems.

Most important is the fact that the EMIRM allows the important actors in Emergency Management system development i.e., emergency managers, tool vendors and system developers *to share a detailed, common basis for their cooperation.*

The rationale for the EMIRM

The authors believe the EMIRM can constitute a significant contribution to Emergency Management for the following reasons:

- Members of the Emergency Management community are greatly preoccupied with standardization of software and data used during emergencies. Their goal is to create significant synergy between the the skills and means of all actors involved. The EMIRM seeks to define a standard "Universe of Discourse" in the domain of Emergency Management i.e., allow different systems and their users to define the cooperation between themselves based on a common set of concepts and references. The "universe of Discourse" approach has been developed for and successfully used in other application domains (e.g., information system development as demonstrated in the European Software Factory project).
- A similar Reference-Model approach has proved very successful in other fields of engineering (e.g., [5], [6]) in even less favorable conditions i.e., a market where several established, conflicting commercial product offers are vying for a share.
- The baseline technology necessary to implement such an approach is already mature, with some components based on accepted industry standards. Distribution is addressed by OSF/DCE and OMG CORBA both of which are implemented by Commercial Off The Shelf (COTS) products. Message-based architectures are being standardized by industry leaders participating in the the CASE Communique group[5].
- This approach facilitates agreement and standardization on the conceptual level, while reckoning with the market-pull towards multiple-vendor offers. Some degree of integration is thus immediately supported which would not otherwise be possible if addressed exclusively at the implementation level.

7 The paradigm of the EMIRM

Although the EMIRM (see figure 1) can form the basis for many different implementations it is nevertheless based on several principles which clearly orient its underlying system paradigm:

- Each Emergency Management information system consists of

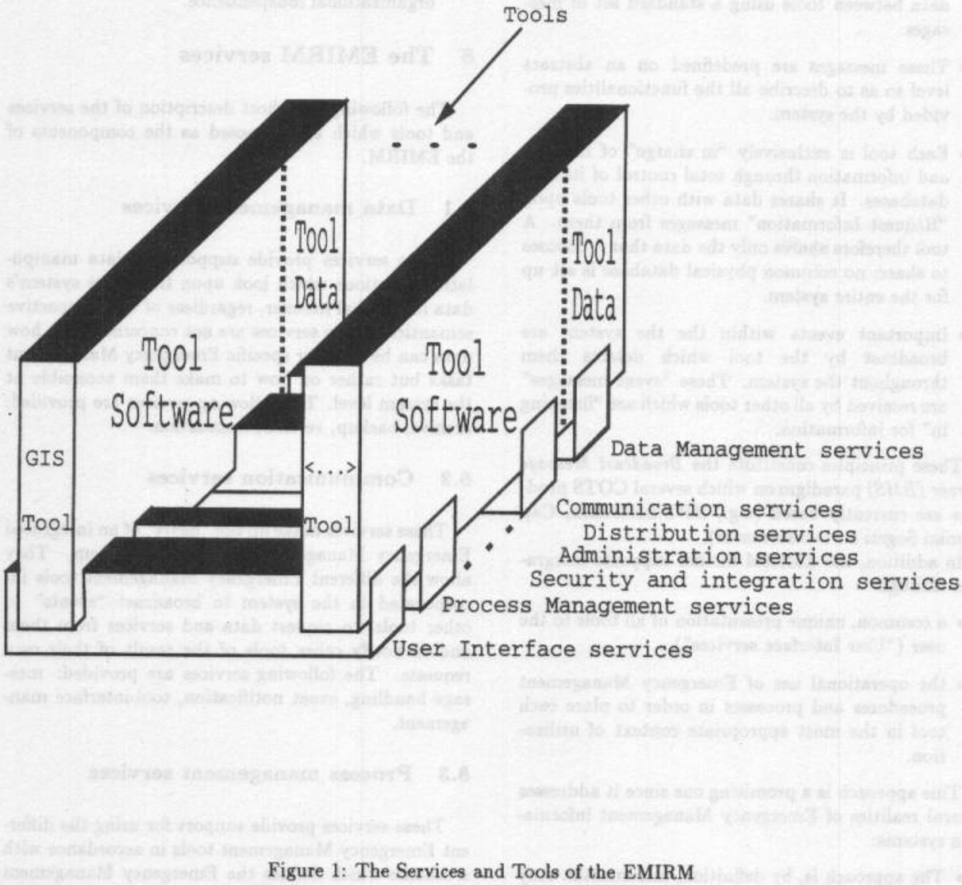

Figure 1: The Services and Tools of the EMIRM

- *software tools* which provide "visible", end-user functions.
- standardized *system-level services* which provide "invisible glue" i.e., integration between the above tools.

- Integration is achieved through the exchange of data between tools using a standard set of messages.
- These messages are predefined on an abstract level so as to describe all the functionalities provided by the system.
- Each tool is exclusively "in charge" of its data and information through total control of its own databases. It shares data with other tools upon "Request Information" messages from them. A tool therefore shares only the data that it chooses to share; no common physical database is set up for the entire system.
- Important events within the the system are broadcast by the tool which detects them throughout the system. These "event messages" are received by all other tools which are "listening in" for information.

These principles constitute the *Broadcast Message Server (BMS)* paradigm on which several COTS products are currently based (e.g., HP's Softbench, Cap Gemini Sogeti's ProcessWeaver).

In addition, the EMIRM further supports integration through

- a common, unique presentation of all tools to the user ("User Interface services"),
- the operational use of Emergency Management procedures and processes in order to place each tool in the most appropriate context of utilization.

This approach is a promising one since it addresses several realities of Emergency Management information systems:

- The approach is, by definition, incremental. Any "external" tool can be made to exchange messages with the "tools" and "services" through the addition of a standard BMS software layer to the existing software.
- No database, common to all tools, is set up. Such common databases are very difficult to develop and even more difficult to maintain and update.
- The tools,,*and their different users*, retain total control over their data. Their participation in an integrated system in no way jeopardizes their organizational independence.

8 The EMIRM services

The following is a short description of the services and tools which are proposed as the components of the EMIRM.

8.1 Data management services

These services provide support for data manipulation functions which look upon the entire system's data in a global manner, regardless of their respective semantics. These services are not concerned with how data can be used for specific Emergency Management tasks but rather on how to make them accessible at the system level. The following services are provided: archive, backup, version, transaction.

8.2 Communication services

These services make up the "heart" of an integrated Emergency Management information system. They allow the different Emergency Management tools incorporated in the system to broadcast "events" to other tools, to request data and services from them and to notify other tools of the result of their own requests. The following services are provided: message handling, event notification, tool-interface management.

8.3 Process management services

These services provide support for using the different Emergency Management tools in accordance with a scheme which defines the Emergency Management life cycle. Indeed, the Emergency Management process can be defined in terms of tasks to be performed, actors performing them *and the software tools needed to carry out each of them.* The process management services therefore provide the link between the organizational aspects of Emergency Management and the underlying technology enabling their utilization.

The following services are provided: process monitoring, process enactment, process scoping.

8.4 User Interface services

The user interface services provide common means for all Emergency Management tools to communicate with the user i.e., presenting the system's information to him/her through controlled dialog. These services thus allow the user to have a single, coherent perception of all the components in the system through display and input mechanisms common to all tools e.g., dragging objects between windows.

The following services are provided: dialog management, display management, user assistance, error message handling, internationalization.

8.5 Security services

These services provide support for the control of access to the system and the rights of different users to execute different operations through this access. The provided services are: operation control, tool enactment, authentication.

8.6 Administration services

These services provide support for the system managers (*not* the emergency managers) in the day-to-day monitoring of global system operation and performance. The following services are provided: system log, statistics, file and tool activation.

8.7 Distribution services

These services provide support for satisfying one of the major requirements made on emergency Management information systems: operation within a distributed working environment. Distribution implies that while users, tools and databases are located on remote sites they still need to cooperate within a close-knit organization. The following services are provided: location, network.

8.8 Emergency management tools

Although different Emergency Management information systems can be required to support very different sets of functionalities it is expected that all such systems will be requested to provide some level of support for certain reoccuring functions. For the need of the EMIRM it is assumed that each of these functions is implemented by a distinct software entity i.e., tool.

The following tools are provided: geographic functions, dialog management, emergency procedures management, risk assessment, evacuation management, training.

Of particular importance are the geographic functions. Indeed, these functions can in some cases form, on their own, the nucleus of a small-scale Emergency Management information system which satisfies many user requirements. Nowadays, these requirements can be satisfied all the more efficiently as many high-quality GIS COTS are currently available.

9 An implementation based on the EMIRM

The MEM*brain* project is currently the single most ambitious European project in the development of information technology for Emergency Management.

Within the project the EMIRM has been used during the preliminary phases in the aim of:

- clearly defining those emergency management tasks which stand most to benefit from the use of information technology,
- giving the different functions their respective priorities within the project's different applications,
- allowing a distributed, international tool development process given a the common reference framework.

The use of the EMIRM has had a clear influence on the MEM*brain* system architecture inasmuch as it is based on a specific integration paradigm i.e., broadcast messaging. Nevertheless, the project unites 9 partners in 6 different countries thereby making system heterogeneity a central issue to be reckoned with. The use of the EMIRM has allowed the different applications using MEM*brain* technologies to make divergent baseline choices in areas such as GIS, DBMS and User

Interface with minimal effect to the common development process and results.

Moreover, the use of of the EMIRM has made it possible for the MEM*brain* project to develop Emergency Management tools and services which are then included in applications based on different system platforms. Several of these applications incorporate legacy software and databases. Utilization of the EMIRM has allowed to upgrade the results of past investment for use in a state of the art environment.

10 The evolution of the EMIRM

The MEM*brain* experience has shown that the EMIRM can form the basis of an international effort aimed at opening Emergency Management information systems to each other and to the wide offer of information technologies currently available.

The authors are encouraged by the fact that similar efforts in other fields of information system integration have proven very successful over the past three years (Object Management Group, Open Software Foundation, Case Communique, European Computer Manufacturers Association).

In this perspective it would be necessary to set up a moderated, international working group bringing together Emergency Managers and technology providers. This group will:

- Widen the current scope of current service definitions. This activity has already been started by analysing each service through several complementary angles or "dimensions", each service description thereby consisting of an analysis of this service through this dimension. The following useful dimensions have been identified: conceptual, external, internal, related service, application, examples.
- Define, at a conceptual level, the Emergency Management Universe of Discourse including all the entities, operations, actors, their integration and their respective roles.
- Match the EMIRM with available tools and systems in order to establish an in-depth state-of-the-art.

These activities form a necessary condition to the acceptance of an Emergency Management standard further down the road.

Acknowledgements

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Information Integration for Emergency Management and Engineering

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ABSTRACT

Emergency Management and Engineering require the integrated analysis of widely disparate information. By the very nature of many "emergencies" it is not always possible to predetermine the essential information required or its location and access requirements. Relevant information usually spans a wide variety of data types. Much of this information resides in and is maintained by a number of independent agencies. Many potentially useful analysis tools (e.g., GIS, remote sensing analysis, surface and sub surface flow models) require access to large data sets of context dependent data. Unfortunately, much of the potentially useful data is fragmented between agencies, inconsistent, underutilized and often inaccessible; this has been called "information grid lock". Much potentially useful information is not available unless there is a substantial investment of expertise and time in data acquisition and inventorying. While some agencies and organizations have attempted to remedy this problem by developing useful specific data inventories and checklists, that can be used on stand alone computer systems, there is a requirement for an integrated information system containing: static and dynamic information, rule and knowledge bases and decision support and analysis tools. This paper proposes an approach to and issues associated with developing a emergency management shared information resource based on networked resources accessed through information "access agents" at local and remote sites.

INTRODUCTION

Managing and planning for major emergencies involve important environmental, business, social and governance issues that require integrated analysis of extensive disparate information. Many of the issues may have contradictory attributes. While it is possible that one major event may be the primary danger, it is usual that many important associated (i.e., secondary) risks must be identified, analyzed and managed. It is even conceivable that, over time, a secondary risk might emerge as a more significant danger than the original event. The potential impact of most emergencies can be measured only by careful consideration of many aspects of the specific area(s) under threat. Without computational support, the management and engineering related to emergencies would be intractable. The diversity of aspects and their dynamic and spatially specific nature clearly indicate that it is a significant challenge to develop a self contained system that can have sufficient information resources and capabilities to be ready for use with all emergencies. An approach that facilitates information sharing is essential for success in emergency management and engineering.

THE INFORMATION CONTEXT

Since major emergencies cut across many aspects of human and biotic activity, most line agencies of federal, provincial (i.e., state), and local government are involved along with effected citizens, community groups and business. A broad base of information is consulted even for "routine" emergencies. Table 1 shows an example of the general classes of location and event specific information that may be required (see Newkirk, 1993, for a more detailed list).

Assembly and use of appropriate information is complicated by the fact that there is often significant overlap between responsibilities of the agencies and various levels of government. Many of the agencies concerned have extensive relevant information and standards that could be applied. Since spatial representation is critical to environmental problem solving (Parks, 1993), this requires the use of detailed spatial data stored in various agency geographic information (GIS) or remote sensing systems. These

Table 1: Example General Classes of Location Specific Information

- environmental attributes (physical)
- environmental attributes (living communities)
- environmental processes
- social attributes (eg., distribution of populations by type)
- social facilities (eg., evacuation receptor capabilities, hospitals)
- agricultural attributes
- distribution of infrastructure
- infrastructure capacity and condition
- chemical processes (i.e., possible outputs of the emergency)
- chemical remediation procedures
- mandated notice and response procedures

files can be very large. For example, one remotely sensed image can require 10^9 bytes of data storage (Goodchild, 1993). But, emergency management and engineering systems need to process more than raw data sets. Processed data, event logs (with spatial descriptive information), parameters, knowledge bases and rule sets, threshold data, etc., must be included. Clearly, the emergency problem space could be characterized as *potentially "data rich"*. This has led various parties to suggest that a major standards definition initiative is required. One approach to system development has been to acquire, in advance, data from many agencies and store it as a large data base on a large "server" type emergency information system computer. Some software developers and local authorities are pursuing this approach. However there are several draw backs -- including: system vulnerability and legal liability.

System Vulnerability

The concentration of main emergency information files on one system implies that it is expected that the system will be available and easily used whenever an emergency condition exists. A major emergency may lead to the loss of the computer's site integrity and functionality. The large volume of data stored on site would make it hard to relocate such a computer in emergency conditions -- yet, this would be required if it was the only main repository for detailed local area data. While it is possible to counter this by developing redundant systems with full copies of the large data bases, this is not practical financially and would be very difficult to manage.

Legal Liability

Developing emergency plans and responding to emergencies leads to the selection of choices and the commitment of resources. This means that there could be exposure to legal liability if there is inadequate consideration of the necessary information while developing emergency management plans or determining remedial actions. For example, corporations, citizen groups, or municipalities could seek legal remedies if mandated actions were not considered, appropriate lead agency information was not consulted, or if some of the data was: incomplete, out of date, or at the wrong scale. Those attempting to develop a self contained emergency information system that contains its own archival storage of all possibly relevant information is faced with the challenge of avoiding data obsolescence and maintaining data set completeness. Failure to do this effectively opens the risk of legal liability. To avoid some of this liability, and manage information storage demands, it is best if an emergency management system obtain the required data sets *when required* by directly accessing the appropriate lead agency's data sets. Essentially, this can transfer much of the data accuracy and completeness liability to the lead agency that maintains the information.

Difficulties in Data Access

Unfortunately, the largest portion of potentially useful public agency data is of no practical use in emergency management and engineering because it is not accessible. While some agencies have produced, for broad emergency community use, valuable reference data sets on disks and CD ROM (eg., a directory of chemicals that cross references: manufacturers, labeling, toxicity and recommended remedial management), these tend to be only current to the data set's specific release date and not specific to local areas. An agency using CD ROM data needs to develop management procedures to ensure that all of its CD ROM data is up to date. Important dynamic information files are beginning to be developed (eg., the Province of Ontario requires the transporters of hazardous chemicals to log manifests, transportation routes and schedules in a provincial data base) and access procedures have been established. On the other hand, for large volumes of area specific data, the actual information holdings are not published, data formats are not defined and access procedures have not been developed. Often, it is impossible even for departments within a government agency to gain access to an other department's information in the same agency. Surveys of government agencies at every level (federal, provincial (state), and local) usually reveal that information is often located at diverse sites, possibly in non machine readable format or on incompatible hardware platforms, perhaps stored in incompatible proprietary software systems, and usually very poorly indexed. It is not surprising that some hold out increasing hope that common data standards will overcome some of these difficulties and actually facilitate information exchange.

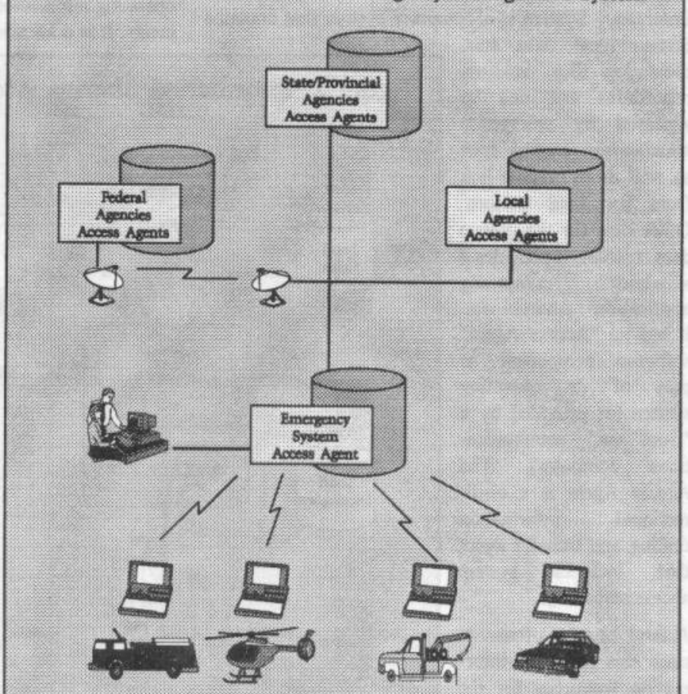
Many computing related standards already exist. For example, a large commercial GIS is subject to approximately 1,000 standards (Dangermond, 1993). In spite of these standards, it remains difficult to access GIS operations and results from external processes and systems. Existing standards have helped with the import and export of files in some selected standard formats; however, the main geographic information and GIS operations take place in proprietary internal structures (Oswald, 1993).

Developers of emergency management face a number of formal and informal standards that help only partially with information requirements. Emergency management systems and applications must draw upon and interface with many subject areas where there are already partially developed formal and *de facto* standards. Agencies with potentially valuable data are mainly concerned with their own use of the data and are unlikely to make major changes to accommodate external needs. Even with an initiative by the Emergency Management and Engineering Society to begin the development of emergency system standards, it is likely the impact will be modest at best and will take some time to develop. The orderly development of emergency management systems requires a strategy to provide effective information access.

INFORMATION INTEGRATION FRAMEWORK

A computing framework that facilitates sharing of environmental information is under development at the University of Waterloo (Cowan et al., 1994a,b). Its fundamental goal is "to enable its users to locate, acquire, and process information relevant to a problem, and then present results in a meaningful fashion". It is a flexible infrastructure (independent of specific hardware and software platforms) to expedite acquisition and utilization of information by improving the connection

Figure 1: A Shared Information Emergency Management System



between *Resources* and *Use*. The operational objective is to seek out and access data resources through a system of "trusted agents".

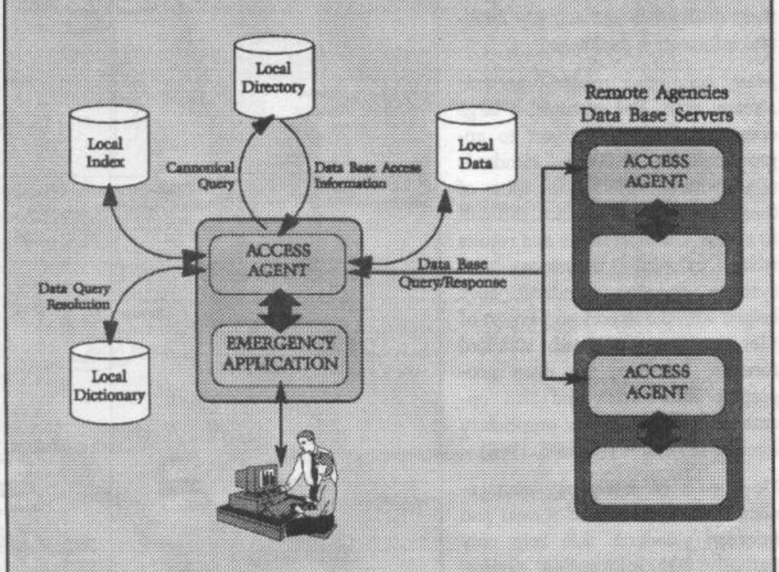
The fundamental principles of this approach can be used to extend earlier concepts of shared information computing (Newkirk and Banz, 1988) for emergency management and engineering systems. By using network interconnection between access agents located in a multitude of agencies and locations, emergency systems can gain access to the required current information without having to maintain a large local archival storage.

Figure 1 is a general representation of a proposed Emergency Management and Information System. The Emergency System is a computer system that contains certain local data sets, event log files, analysis procedures and can be accessed by emergency management central staff as well as by remote link from key field stations. Other than for the unique data it stores, it provides a standard computing application environment. It has an "Access Agent" software component as part of its operating system (or provided by a "front end" communications computer). The Access Agent is a bi-directional information finding and transfer agent that includes system access screening.

A large number of remote sites can serve as information resources for the Emergency System through their Access Agents using standard communication network services (possibly, satellite data communications will be used in major systems). Thus, Federal, State/Provincial and various local agencies can be accessed as required depending upon the nature of the emergency. The Access Agent is designed to be a standard component that is added to each of the systems willing to cooperate in information sharing.

Figure 2 shows the proposed basic Access Agent architecture. Each agency's Access Agent contains the same functional components -- although each will contain different information depending upon the mission of the owning agency and its resources. *Local Data* consists of the sets of information held by the local system. *Local Data* is partitioned into the data that may be accessed remotely, and private information. The *Local Index* maintains information about the location and technical and functional specifications of local sharable files. A *Local Dictionary* is included to assist users and operating applications clarify their information requirements. It is a knowledge based subsystem that provides searching and pattern matching functions. A *Local Directory* provides to both external and internal users and applications information about data bases, rule bases and tools. Normally, sharable information is stored in a standard (i.e., canonical) form. If the data is available in canonical form, the *Local Directory* so

Figure 2: Information Sharing Access Agent



indicates; otherwise it provides the specification (defined by the information owner) of transformation functions or procedures that allow the information to be accessed in perhaps one of several canonical forms. This means that the data set owner need not reformat its data as long as it indicates how the data can be accessed.

When a running emergency application seeks information that is unavailable its local system, the Access Agent uses standard "request for information" polling in the distributed network. This may be a general request when the local Access Agent has no specific knowledge of possible sources, or the request may be directed to a specific agency's Access Agent by information obtained from the *Local Directory*. (In other words, the local directory and index services can be customized to speed up information searches.)

A key feature of each Access Agent is its role as a "trusted agent" (see Cowan et al., 1994a,b) that incorporates standards for access control (and, if appropriate, access charges). The trusted agent is simply a process that intervenes in all accesses to a database. Its protocol is defined by specification of the information sharing framework -- but the actual implementation of the trusted agent operation is the responsibility of the data provider since different agencies will wish to assign different levels of control.

Advantages

This approach does not predetermine a specific character of the resources in the data sharing framework. Nor does it specify operating systems, hardware platforms or application software. Data providers are encouraged to make information available without requiring them to complete major resource transformations. The framework is defined to deal with data sets, knowledge and rule bases, etc., as defined by any basic standard. Therefore it does not require a major new standards definition exercise. Willingness of agencies to cooperate should be maximized because the framework does not require participants to change their own standards or procedures. Since the approach is not hardware or software systems dependent, and since it encourages the holding of smaller local data archives, system portability and relocation prospects are enhanced. This reduces concerns of system vulnerability and legal liability.

A prototype framework for environmental spatial information is being implemented at the University of Waterloo, based on standard network protocols and in association with Federal, Provincial, and local municipality research partners. The development should have a large impact on the development of shared emergency management and engineering systems as well as environmental information systems generally.

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AUTOMATED EMERGENCY MANAGEMENT: A PROPOSAL FOR A STANDARDIZED SYSTEM

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ABSTRACT

The failure to adequately prepare for and respond to disasters has taken an unprecedented toll in recent years. However, two trends present important opportunities to improve this situation. The first is the development of the profession of emergency management, which will benefit from the application of standardized strategies and practices. The second is automation, where microcomputers and software are now both affordable and user-friendly.

We can now develop and implement a nationwide automated framework. This can ameliorate a wide range of deficiencies and inconsistencies in emergency management programs across the country. Recent developments in microcomputer hardware and software allow exhaustive background information to be presented through CD-ROM and critical guidance to be provided through decision support systems. The proposed project will apply these technologies in building an automated framework. Additionally, it will provide standardized interfaces to incorporate existing software and facilitate future innovations in automation for emergency managers.

INTRODUCTION

The profession of emergency management stands to gain much by fully integrating the use of microcomputers. Automation has transformed most endeavors. Expanded capabilities for information storage, word processing, communications, and artificial intelligence have lead many emergency managers to believe that this is the most significant innovation during the last decade. With qualified leadership extensive implementation can be anticipated during the 1990's.

Considerable progress has been made in advancing emergency management. However, at the local level there remains a lack of continuity among the elements which comprise this broad field, as well as a need for standardized practices and expectations. Perhaps more importantly, those on the front line often find themselves confronted with a bewildering array of information to sort out and decisions to be made when planning, responding, and attempting to recover from a disaster.

The key to emergency management is placing effective systems where they need to be. Emergency management is ultimately practiced at the local level. Our national "de facto" system places the onus of responsibility on the local jurisdiction, with higher levels of government supposedly in support roles. Moreover, the impact of disasters tends to be localized, though as the recent floods illustrated, this can be a string of localized impacts tied together. It would follow that automated systems should be oriented around the needs of local level emergency managers and should be realistic about the constraints under which they operate.

The problem is that local jurisdictions' efforts in emergency management are largely inconsistent and unstructured. Certainly there are exemplary programs in place, but for the system to be effective, implementation must be widespread. Disasters can strike anywhere. They tend to have the most impact on smaller jurisdictions which are not fully prepared. We need only look at the sites of recent disasters: hurricane damage in Homestead, earthquakes in Santa Cruz and Landers, conflagration in Laguna and Malibu. Emergency management is complex, expensive and time consuming. Developing an effective system is difficult, particularly for smaller jurisdictions that do not receive adequate support.

The National Academy of Public Administration (NAPA), at the request of Congress, conducted a study of the nation's emergency management. NAPA concluded that,

> ...cooperation is necessary to achieve effective emergency management from the beginning to end in any stage... The intergovernmental system as a whole is only as effective as its weakest part. The Federal Emergency Management Agency (FEMA) must strategically allocate resources to improve the system; where capacities are low they need to be raised and where inconsistencies exist they need to be reduced. (p. 88)

The role of higher levels of government should be shaping and coordinating the overall direction of what is ultimately implemented at lower levels. The NAPA report indicated a role for FEMA in improving the nation's emergency management system. Widespread and consistent use of automation is the obvious means of accomplishing this. The questions are what will such a system look like and how can this be accomplished.

OBJECTIVES

There are two primary objectives to this project: standardization of practices and an automated framework. This project should be viewed as a catalyst, bringing together the best in practice and automation. The end product will be microcomputer based software which serves as a self-contained resource sufficient to guide emergency managers at any stage in the development of their program. Well proven practices and the most promising technologies can be applied in developing a truly integrated and comprehensive approach to emergency management. This can serve as a demonstration project and the basis for standardization, displaying in one location the best in emergency management. With this as a practical basis, the entire program can be automated, thereby streamlining the flow of information.

AN OPTIMAL SYSTEM

The key is to provide the foundational work upon which others can develop new projects or integrate existing systems. Inherent in this is establishing standard interfaces for software to communicate. Furthermore, it will be critical to utilize appropriate forums and networks to stimulate further innovation.

This will be a stand-alone, user-friendly, interactive system containing the following elements:

- Artificial intelligence will be utilized to assist decision makers in the process of program development, as well as response and recovery operations.
- Comprehensive background materials will be provided through CD-ROM. Strategies will be presented, together with in-depth information, which can be accessed as required.
- Periodically updated guidance will be available through CD-ROM and networks.
- Standardized documents will be presented for meeting planning requirements. The system will be able to reproduce in hard copy all essential guidance materials for response and recovery operations, providing a backup in the event of a catastrophic failure of the automated systems.
- Realistic training and exercises will be presented, integrating specific information on the jurisdiction's capabilities and hazards.
- Options will exist for integrating the graphic display of information through existing mapping systems.
- Communications platforms for both local area and wide area networks will be provided.

• Resource and expenditure information extracted from response data will be linked with guidance on FEMA financial reporting requirements. This will ensure accurate, timely, and complete reporting for reimbursement.
• The system will establish standards by which peripheral software can communicate with this core system.
• This will be a heuristic system which can adapt itself to the needs and capabilities of the user.

If properly designed with a forum for feedback and innovation, a host of other practical applications will emerge as the project matures.

THE HUMAN ELEMENT

It is important from the very start to realize that automation is not a substitute for the human element in emergency management. Rather, it should be viewed as a tool to expand human capabilities by enhancing the ability to communicate and process huge amounts of information during stressful events. The proper use of automation is often overlooked as the advocates of this powerful new technology promise more than is appropriate.

Emergency management is a human endeavor. No amount of automation will replace the requirements for informed exercise of sound judgment. Effective decision making during disasters seems to stem from the ability elicit the essence of the situation which is developing and intercede based upon what is projected to emerge as the scene unfolds. Dr. Jacques Vallee states:

> Crises, by their very nature, are irrational processes. People who are good at managing crises tend to be people who have gotten very, very good at making decisions in almost the total absence of information, making gut decisions based on who they could trust and couldn't trust. (cited in Chartrand, p.205)

The ability to improvise is essential. Automation should focus and enhance the human element in emergency management without stifling the process.

In disasters a tremendous number of minor events, all linked sequentially to one triggering event, are unfolding at varying rates. Accurate monitoring of the situation is essential for decision making. There are limitations to the amount of information one individual is able to effectively assimilate. Automated systems are the only practical means for managing this information. Systems must identify essential elements of information, present it logically, and remove unimportant information. Another way of viewing this is that two levels of information must be managed simultaneously. The emergency manager must maintain the "macro" view of the entire event, while at the same time being able to take a "micro" view of the details of specific parts of the event.

Much of the literature surrounding the application of automation in general tends to present it as a panacea. Technology is not going to offer the solution to the complex problems inherent in disasters. However, technology does present an effective means for managing information. This, in turn, leads to more effective decision making at the human level.

UNDERSTANDING THE ADOPTION OF INNOVATION

Clearly, emergency management will benefit from an automated framework. The fundamental question is how to implement such a system. The work of Drabek on the adoption of new technology offers important insights in this area.

Of particular concern are the use of "pull" factors and incentives. In this area, Drabek draws upon the work of Abernathy and Chakravarthy, who identified the role of the federal government as the primary influence in the adoption of innovation. Their investigations focused on the impact of the federal government on the adoption of a wide range of new technologies. They found that government has essentially two options: (1)

"push" innovation by creating a new technology or (2) "pull" innovation along by altering standards so that the technology or market must change, making new technology necessary. Push strategies are characterized by government funded research and development or demonstration programs. Pull strategies can include such incentives such as persuasion campaigns or the heavy handed use of regulatory intervention. The conclusion was that the "push" strategy was less effective and more likely to fail than a "pull" strategy. (Abernathy and Chakravarthy, p.3-18)

It is preferable to gain adoption of new technology by more passive means, rather than by government development of the product. Drabek cautioned that no research was located which would indicate if this general principle is applicable in the field of emergency management (p.32).

A combination of pull strategies and pushing through direct involvement in the development of a core system might provide the most effective means for gaining widespread use of this technology. FEMA should develop the core of a program for automation and establish standards by which other elements will interface. By the use of "pull" strategies, FEMA can gain acceptance for automation at the local level.

FEMA has an opportunity for developing incentives. Emergency management is accomplished relatively independently at the local level, yet the federal level through FEMA bears the financial burden for the failure of these programs in the unfortunate event of a disaster. It would follow that FEMA should be able to dictate how programs are structured at the local level, if they hold ultimate financial responsible for their success or failure. Inherent in this is the opportunity for FEMA to provide an incentive for participation in an automated system at the local level. This approach is being utilized in a similar undertaking in California.

CALIFORNIA, SEMS, AND AN OPPORTUNITY

California is engaged in the development of an exciting and promising approach to emergency management. Called the Standardized Emergency Management System (SEMS), this common-sense approach is an outgrowth of the 1991 conflagration in Oakland. Problems encountered in fighting these blazes highlighted deficiencies in emergency management. As a result of the this fire, State Senator Petris introduced SB 1841 directing the Governor's Office of Emergency Services and other agencies to develop the Standardized Emergency Management System (SEMS). It is to be used by all disciplines and all levels of government. The framework of SEMS is the Incident Command System, the Multi-Agency Coordination System, the Master Mutual Aid Agreement and related mutual aid systems, and the operational area concept.

The caveat is that the State will not require local jurisdictions to follow SEMS. However, the State will withhold financial reimbursement following a disaster for a jurisdiction not meeting the requirements of SEMS. It remains to be seen if the State is actually capable of such a measure following a disaster. The financial implications are considerable, not to mention the political repercussions. However, the essential principle is sound: if a local jurisdiction expects post-disaster financial assistance from a higher level of government, it is only reasonable that certain requirements be made of that jurisdiction's ability to respond to disasters.

FEMA is carefully watching SEMS in California and considering how a similar type of system can be implemented nationally. The principles of SEMS dovetail with the proposed automated framework. Moreover, automation provides the most efficient means for widespread implementation of a standardized system.

A STRATEGY

The key is to develop the foundational program and provide nationwide distribution to the local level once reasonably well refined. Such a system is beyond the financial means of the jurisdictions which need it most. Therefore, it follows that the system should be developed and implemented with federal funding.

A partnership between agencies at the federal and local level can provide the synergy necessary for developing a project of this type. Since this is a tool ultimately to be used to enhance frontline emergency management, it is best developed in the field by people intimately familiar with the real problems faced.

Two approaches are appropriate for developing this project: High Performance Work Teams and Delphi studies. Using a High Performance Work Team approach, various disciplines can be brought together to work on specific aspects of the overall plan. Using a modified Delphi study through the Internet, a wide range of experts can be consulted on specific aspects and their feedback synthesized. The synthesized work can then be returned to the experts for their modification, with a final synthesis being the outcome. This approach allows us to develop consensus among key players while gaining clear direction in program development at various stages.

After development, the project should shift focus so that it can be injected into the mainstream. Distribution can be done throughout the United States. As an incentive for participation, the project can be tied to recovery funds or to other opportunities. Eventually such a project can be used world-wide through an entity willing to provide global leadership.

The International Decade for Natural Disaster Reduction (IDNDR) can provide the context for developing this system. This project can offer focus and energy to the United States' contribution to the IDNDR, bringing together many worthwhile and imaginative efforts in a unified system. It presents a cost-effective approach which can be universally applied, and easily adapted to specific locales. The application of this standardized approach world-wide can improve international cooperation and effectiveness in all phases of emergency management.

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BIOGRAPHICAL NOTES

Steven Jensen is the Disaster Preparedness Specialist for the City of Long Beach, California. He is responsible for developing the emergency management program for this highly urbanized city of approximately one-half million people.
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THE FUTURE OF EMERGENCY MANAGEMENT

The Intelligent City and Emergency Management in the 21st Century

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ABSTRACT

The emergence of the intelligent city in the 21st century will radically transform emergency management as we know it today. Computing and telecommunications technologies, once separate and well-defined, will merge and their distinctiveness will blur. Mobile wireless and Metropolitan Area Networks (MANs) will serve as the telecommunications backbone over which municipal management information systems will synchronize and orchestrate the various functions of government agencies and departments. Traditional organization and separation of municipal departments and agencies will undergo significant change as the intelligent city makes interdependent relationships more concrete and dynamic. Resource allocation will become more efficient as implementation of comprehensive planning becomes more tangible. Rather than existing largely as a separate and distinct function which is called upon during times of crisis as it is today, emergency management will become integrated into every facet of municipal planning and operations. The intelligent city will incorporate each of the elements of emergency management (preparedness, response, recovery, and mitigation) into its overall planning and operational matrix.

INTRODUCTION

In the hundred years or so since its introduction, the automobile fundamentally changed the world, its effects can be seen having shaped both cities and institutions. Similarly, digital technologies, which are still in the their genesis, will, over time, have impacts of equal or greater magnitude, reshaping our cities and institutions. The role of emergency management in ensuring public health and safety will be modified by the coming changes. What form these changes will take can be surmised by evaluating trends in emergency management, government, industry, education, telecommunications, computing, and cybernetics.

CYBERNETICS, AUTOMATION, AND INTELLIGENCE

The field of cybernetics holds the key to the intelligent city. Cybernetics is the study of control and communication processes in electronic, mechanical and biological systems. Cybernetics has the ability to synthesize and simulate intelligent systems and can provide the means for improving planning, decision–making, and problem–solving processes, in some cases automating them. Introducing automation requires planning, which implies prediction and control, all of which requires communication. The emphasis in design and planning within the context of applied cybernetics in the intelligent city will be flexibility, with a built–in capacity for change. The total system will be dynamic, where various subsystems can adjust as required to maximize the well being of the whole system. Such adjustment will be affected by a concept in cybernetics called "negative feedback", wherein systems modify their behavior in light of changes in the environment. Real–time modeling will occur whereby subsystems can run "what ifs" and then feed the results to a central processor which compares all subsystem results and passes either positive or negative feedback to subsystems. The desired results of one subsystem will thus be in relation to all other subsystems affected. An optimized condition is reached when all subsystems therefore act as one toward achieving the desired goal. Lack of organization, interagency conflict, inefficient use of resources, and other problems oftentimes encountered in emergency management will no longer be commonplace. In a reductionist sense, many of these problems can be attributed to barriers of time and space which are rapidly breaking down.

THE CITY AS AN ORGANISM

To better understand the concept of the intelligent city it is helpful to draw an analogy with the natural world. With 13 billion years to equilibrate and optimize, natural systems are a superior model for perfecting manmade systems. Organisms naturally tend towards homeostasis, a condition of physiological equilibrium produced by the balancing of functions within the organism. In homeostasis a change of state in one part of the system elicits a response from other parts of the system to maintain balance. The intelligent city will, in many respects, operate very much like an organism, monitoring its various component systems and responding accordingly to potential or actual changes of state in order to maintain equilibrium. This sensitivity to potential or actual changes affecting the equilibrium of the city will have important ramifications on emergency management. As conditions favoring disaster are detected, the intelligent city will respond accordingly, heightening readiness as appropriate. The intelligent city will assimilate knowledge of hazards and implement hazard mitigation as an integral component of its overall functionality. As feedback processes are built into the intelligent city, the system will learn from its mistakes and improvements will occur. This learning capability already exists today, albeit in a rudimentary form, in neural networks.

When an organism experiences a pending or actual change of state, information is distributed among and between all other parts of the system and changes are made accordingly. For example, if food is absent, the metabolic rate might slow down as the organism seeks homeostasis. Similarly, when a city is threatened by a pending or actual hazard which puts lives and/or property at risk, emergency managers interact with different departments and agencies in anticipation of changes which must be made to reduce losses or avoid them altogether. Emergency management is basically all about managing and coordinating a complex system. While the organism has a highly responsive information collection and distribution system consisting of a brain and nervous system, the city as we know it today does not. The vulnerability of man's artificial environment exists today because of the absence of an effective communication and control system, creating a permanent condition of asymmetry which leaves society open to disasters. As telecommunication and computing technologies are used to interconnect all municipal subsystems, the city's nervous system will be in place and a condition of equilibrium will be defined. The responsiveness of the city to pending or actual changes will then improve, as deviation away from the optimal condition will be both predictable and correctable.

If we view the intelligent city like an organism, experiencing countless actions and reactions, we can see that unless these actions and reactions are intelligently managed and coordinated, then the system experiences chaos and crisis. When an outside force such as a natural hazard acts upon the system, a disturbance in the system occurs, upsetting the balance and chaos ensues. Catastrophes are the ultimate expression of a natural hazard acting upon a system made vulnerable due to the absence of an effective control and communication system. In point of fact, our definition of a hazard – implying undesirable qualities – is only in relation to the effect it has on our artificial systems. A value judgment is being made. A hurricane is not intrinsically bad, we only view it as such because of our poor adaptation. A good example of this is our proclivity to develop in the floodplain.

In a sense, our disasters are evidence of our failure to model ourselves after biologic systems. The refined control and communication systems in species are principally manifested as self–control, i.e. adaptation, which sometimes implies withdrawal from harmful environments and acclimatization to more favorable ones. In manmade systems this could mean passive acceptance of the hazard (e.g. purposeful undevelopment allowing high hazard areas to revert back to their natural state) rather than active resistance (e.g. strengthening building codes).

TOOLS AND TECHNOLOGY

High bandwidth capacity provided by a combination of both wire (including fiber) and wireless transmission mediums will make connectivity "anytime, anywhere" a reality. Data speeds in the gigabyte and terabyte ranges will carry two–way audio, full motion video, and text between both stationary and mobile locations. Telecommunications and computers will merge, becoming nearly indistinct, and will link the various subsystems of the city, e.g. transportation, energy, waste, etc. through a MAN (metropolitan area networks) into an overall system imbued with intelligence. A single knowledge base, feeding and being fed by numerous subsystems, will serve as the "brain" of the intelligent city. For example, in the event of an emergency, traffic patterns will be changed automatically to permit orderly evacuation and/or rendering of aid. Spatial intelligence, combining information provided by next generation GPS and GIS, will drive radiodirection, radiolocation and navigational guidance systems to pilot vehicles and regulate and disperse traffic flows. Technology for storm prediction and tracking will improve, increasing the reliability and accuracy of preparedness activities (e.g. warning and evacuation). Automated forecasts and historical data will be matched and likely scenarios will be plotted. Computer aided education and simulations using virtual reality will be used for training exercises. Emergency warning and notification systems will extend into the home and the workplace, taking advantage of the "anytime, anywhere" model of connectivity.

Intelligent Assistants

While decision–making in emergency management can frequently make the difference in a life or death situations and we would not wish to place exclusive trust in an automated system, certainly processing the many variables which rapidly change during an incident is beyond human capability and this is where a certain amount of automation can be helpful. Such automation is the domain of the "intelligent assistant" a revolutionary tool for aiding people who perform tasks which cannot be automated.

The intelligent assistant will be the result of combining expert systems, decision support systems and artificial intelligence. They will be portable, appliance–like and will utilize natural language processing and voice recognition. They will be useful for problem solving, outlining emergency procedures and role clarification. The intelligent assistant will be utilized to make situation reports and will provide specific guidance to the user on task ordering and completion. The plethora of incoming reports which are common during crises will be machine filtered, undergoing preliminary checks for accuracy and reliability, then passed onto the emergency manager for consideration as part of his/her decision support system. Situation reports will be fed into the cities' common knowledge base where modeling will occur. Predicted outcomes along with actual and suggested interventions will be implemented and communicated via the cities' control and communication systems. Information on damages and losses will be captured and immediately translated into resource requirements for both response and recovery. Crisis events will be recorded in great detail, capable of replay for simulations and training purposes.

HUMAN FACTORS

It is fairly certain that in the future, public debt, insurance industry losses, and the trend toward greater societal equity will result in an increase in the responsibility the individual bears for his or her actions upon society. Institutions which currently absorb and then spread losses (government and insurance) across society will undergo a transformation as society systematically goes about the business of mitigating hazards rather than creating or sustaining them. How much of this will occur through legislation and how much will occur through market forces can not be known at this time.

As the impact of control and communications systems become widespread, there is a danger of their misuse along totalitarian lines. The dangers of control and conditioning have been amply described in George Orwell's *1984* and Huxley's *Brave New World*. Subtle intrusiveness of sensing and monitoring functions in the intelligent city will create a tension between the rights of the individual versus the well–being of society. Issues of privacy need to be balanced with monitoring activities of people. There is no denying that control can be a threat to civil liberty. In the interest of society, however, it is possible that a reforging of what constitutes the unalienable rights of the individual will occur.

While change may bring about prejudice in people affected, feedback processes in the intelligent city will be personalized to mitigate such adverse reactions. As individuals learn more about how they affect and are affected by others, resistance to change will diminish.

In addition to simple adaptation from negative feedback (reactive), complex adaptation through learning (proactive) is also possible and has the greatest potential for avoiding damages and losses in the future. The lag time between the gaining of new knowledge through experience and the dissemination of that knowledge in ways to effect change will be reduced considerably by improved information capture, processing and distribution. Maintenance learning, i.e. maintaining the status quo, will give way to innovative learning. The separation of education and work will end and the two will become almost indistinguishable from one another. This will occur for three reasons: 1) real learning is experiential, i.e. on the job; 2) the time lag between gaining new knowledge and its implementation is wasting valuable resources; and, 3) a measurable return on investment in creating new knowledge must be gained if further investment is to take place. This has important implications for emergency management in extending hazards reduction into all phases and aspects of society.

GOVERNMENT AND CHANGE

The future of state and local government will be shaped by a combination of forces, including technology, politics, economics, demographics and environmental changes. As futurist Alvin Toffler has indicated in his book *The Third Wave*, strong leadership will be replaced by local and individual action. Government will provide the resources, especially the learning mechanisms, to equip individuals for their increased responsibilities. Government will encourage self-sufficiency in preparedness, response, recovery and hazard mitigation within individual neighborhoods and communities. Government will become less top-heavy, more flat and decentralized, following similar trends in the economy and business sectors. Continued decreases in federal aid will demand that local governments realize greater efficiency and look for economies of scale in service delivery. This will be accomplished by increased privatization of public services and government stimulating self-sufficiency at the local level. Geologic, fire, wind, and flood hazard districts will be created to raise funds for hazard mitigation. Citizens will have more control over the activities of government which affect them. Citizen access to government will increase through direct participation in decision-making via telecommunications, making most, if not all, representative forms of government obsolete. Governments primary job will be to inform and educate.

Local government has become more complex and fragmented. At best departments don't work in concert, at worst their objectives are at complete odds with one another. Applied cybernetics will eliminate the incongruities between government agencies, operating not in isolation but in relation to all other departments and agencies within government.

CONTINUUM AND SUSTAINABILITY

By necessity, planning will play a critical role in the design and development of the intelligent city. Hazard identification will be incorporated into the fabric of infrastructure design, planning and operations. Agency actions will be in concert with one another throughout the municipality as decision-making and plan "checks" will occur with every other agency in the municipality. Within this matrix, planning and operations are a continuum, feedback and corrections are immediate, and accommodation or rejection of innumerable actions take place. Crises either have their origin in nature, or occur through unintentional and impersonal factors inherent in human agency. The intelligent city will detect ever earlier stages of the causations of crises, enabling us to better prevent or minimize them. The relationship between risk and cost will be better understood and individualized. Mechanisms for mutual aid will improve, as cities and states will be linked through what is now taking shape under the guise of the "national information superhighway". Through these interconnections cities will compare experiences and learn from one another. Vulnerable infrastructure in high hazard areas will be identified and systematically retired.

CONCLUSION

Within the intelligent city, emergency management will become more proactive rather than reactive as it is today. Emergencies will occur with less frequency in the intelligent city as "unexpected situations" or "sudden occurrences" will decrease with applied cybernetics. Virtually all of the technologies necessary to construct the intelligent city have already been introduced, albeit some (e.g. natural language processing) in rudimentary form. Technological forces in computing and telecommunications have already precipitated dramatic changes in the manner and style in which cities operate. While we are in the infancy of consciously merging the various components, the groundwork for the intelligent city is already being laid, changing the municipal landscape and transforming both the theory and practice of emergency management forever.

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URBISTICS
REDUCTION OF URBAN POLLUTION AND FOREST FIRE FIGHTING AND SURVEILLANCE

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ABSTRACT

Studies at the Swiss Federal Institute of Technology in Lausanne (EPFL) and the Municipal and Energy Research Center in Martigny (CREM) have led towards the identification of original town management and complex systems concepts. They integrate planning, cadasters, and real time management under the neologism of urbistics. To illustrate an example this presentation deals with the modeling of pollution reduction strategies based on modifications of heating systems and adaptation of the public and private transportation networks in the Swiss conurbation of Lausanne. It also describes the installation of a system for forest fire surveillance and fire-fighting in the Bouches-du-Rhône in France. The application includes the monitoring of fire-fighting vehicles via satellite communication and alerting the population with automated telephone calls controlled by numeric models forecasting affected areas. These two examples show how to employ map based and urban data for the benefit of the public, the public security and the environment. Starting with the concepts and passing through real applications, this presentation covers the stages right up to final realization in order to explain the limits and advantages of these methods. In fact, the strategies for pollution reduction studied are currently imposed on the communities concerned and the fire surveillance and fighting system is already in use in Aix-en-Provence.

1 AIR POLLUTION ANALYSIS MECHANICS

1.1 Case Study

The study of air pollution reduction measures requires detailed knowledge of all of the mechanisms linking causes to effects, in a way that action may be taken against the most significant causes without relocating the impacts. Figure 1 describes the principal stages for the geographic description of emission sources. The emission model creates the relationship between the processes and their characteristics. Most emissions are linked to energy use (figure 2), hence, a good description of the energy demand of households, workplaces and transportation systems, guarantees the detection and description of the vast majority of pollution sources.

Once established, the model can aid the evaluation of the influence on the impacts of various intervention scenarios. These scenarios would include the study of changes to energy processes such as burners or motors, or to different types of infrastructure usage with traffic flow restrictions or

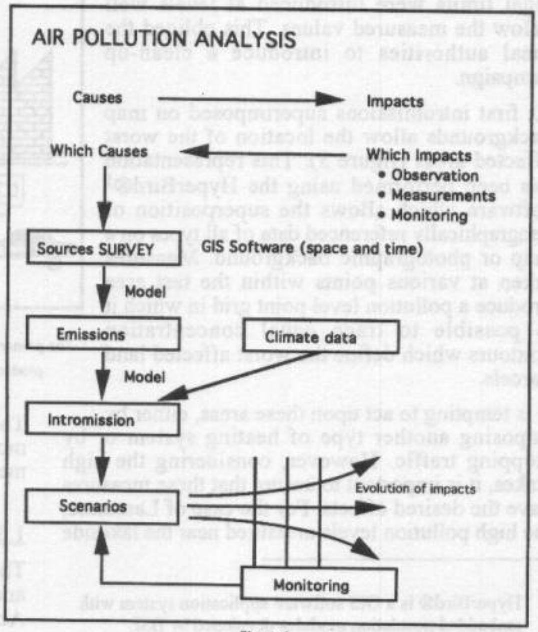

Figure 1

urbanism including the relocation of damaging activities.

At the outset of these intervention scenarios, it is essential to monitor all of the parameters, firstly to calibrate or confirm the models, secondly to verify the success of the measures. Lastly monitoring is required in order to plan for special actions concerning interventions on infrastructures in real-time, such as using cleaner fuels when pollution passes a certain limit, or imposing restrictions on traffic during hot calm weather.

In the wake of smart house concepts which efficiently manage households come urbistics or smart town measures for the optimal functioning of whole communities.

1.2 Intervention Process

Studying the noxious effects linked to air pollution allows us to distinguish the pollution levels observed in order for them to be reduced to within the legal thresholds and, more importantly, below the danger levels.

For the example of Lausanne in 1990, federal legal limits were introduced at levels well below the measured values. This obliged the local authorities to introduce a clean-up campaign.

At first intromissions superimposed on map backgrounds allow the location of the worst affected areas (figure 3). This representation has been performed using the HyperBird®[1] software which allows the superposition of geographically referenced data of all types on a map or photographic background. Measures taken at various points within the test area produce a pollution level point grid in which it is possible to trace equal concentration contours which define the worst affected land parcels.

It is tempting to act upon these areas, either by imposing another type of heating system or by stopping traffic. However, considering the high stakes, it is important to ensure that these measures have the desired effects. For the case of Lausanne, the high pollution levels measured near the lakeside might provoke the initial reaction of banning traffic in that district. However, the indices showed that the pollution could in fact have their source from surrounding neighborhoods, and the concentration near the lake being caused by the topographic and climatic situation. If this is the case, the actions would not have the desired results and would perhaps have caused irreversible economic effects.

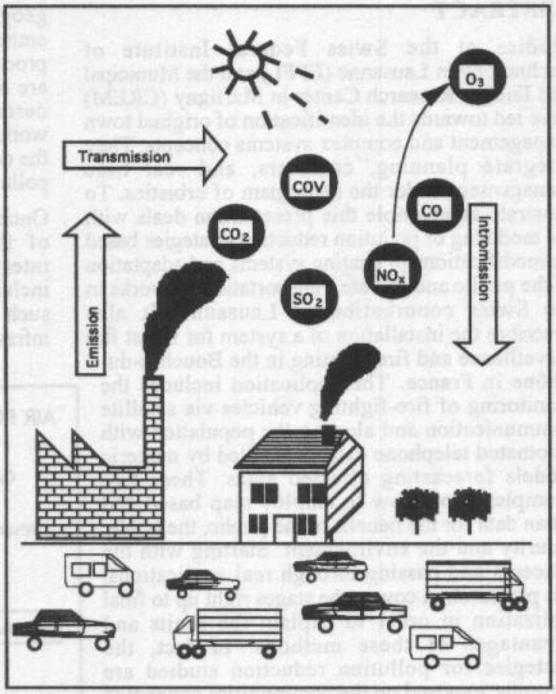

Figure 2
The primary pollutants such as NOx and COV interact under the sun's effect, producing ozone which is a particularly noxious secondary pollutant.

The local authorities decided to build a complete model in order to evaluate the impact of proposed measures.

1.3 Initial Reference State

The three emission generators (heating, industry, and traffic) were modeled using HyperBird®. According to currently available data it is possible to describe the punctual emission levels for known

1 HyperBird® is a GIS software application system with embedded simulation modules developed by BSI, Lausanne

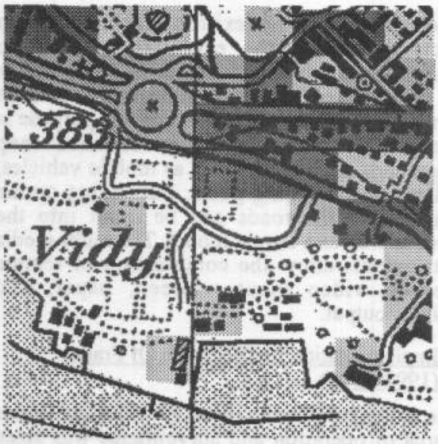

Figure 3:
Pollution levels indicated by the shading of the squares

large scale emitters, linear emission fields for main traffic axes and the emission distribution according to the population density (figure 4).

The emission levels from a combination of heating, industry and traffic were entered into the meteorological model POLYTOX[2]. This model subsequently allowed the study of the transformation and transportation of pollutants in prevailing climatic conditions in order to reconstitute a geographic representation of intromissions. The comparison of measures with simulated intromission allows the calibration of emission and meteorological models. In the case of Lausanne, an acceptable correlation was attained between the measured and simulated intromissions., despite its particular topography including numerous valleys and the thermal effects of the lake

1.4 Construction Of The Intervention Scenarios

The analysis of energetic processes and their improvements allows the identification of the possible emission level changes.

Amongst the processes taken into account are :

- District heating using gas fired co-generation units instead of industrial oil-fired heaters
- Low NOx heaters
- Spread of catalytic converters
- Use of catalytic converters in diesel engines (not yet on the market)
- Offering public transportation enhancements or reinforcement

For each of these processes and rules, it is important to take the market penetration procedure into account

The construction or extension in Lausanne's use of a district heating network can take several decades, whereas, all cars on the road will have catalytic converters installed within the next 10 years, and most of the trucks and heavy equipment presently in service will still be so in 10 years time.

Data concerning traffic generation linked to access requirements to residential areas, businesses and

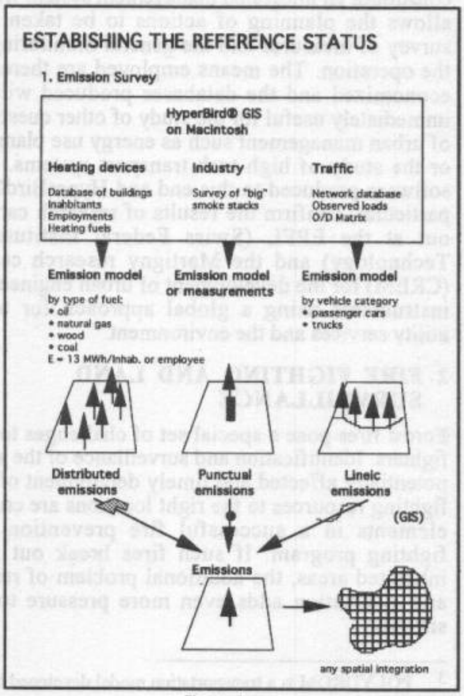

Figure 4

2 POLYTOX is a diffusive-convective 3D concentration model developed by Systems Consult, Bern, with assistance of SEDE SA, Vevey

shopping centers were introduced into the POLYDROM[3] model which allows modal assignment and traffic forecast calculation. An increase in public transportation capabilities, a new freeway exit or a traffic ban changes the traffic distribution and, taking the engine types into account, can produce a new emission state.

Through a combination of technical, legislative or management measures it is possible to construct emission scenarios.

The model POLYTOX evaluates these emission scenarios in terms of intromission. It is then possible to choose the actions which should lead to reduction in air pollution to levels imposed by the law.

This evaluation aids the local authorities in their choice and justification of intervention methods. The system which is set up should guarantee the control of effects and the monitoring of the action.

The combination of these different models, thus constitutes an integrated management system which allows the planning of actions to be taken, the survey of measures and the general monitoring of the operation. The means employed are therefore economized and the databases produced will be immediately useful for the study of other questions of urban management such as energy use planning or the study of high-tech transport systems. The software produced to this end and HyperBird® in particular, confirm the results of research carried out at the EPFL (Swiss Federal Institute of Technology) and the Martigny research center (CREM) for the development of urban engineering instruments using a global approach for town utility services and the environment.

2 FIRE FIGHTING AND LAND SURVEILLANCE

Forest fires pose a special set of challenges to fire fighters. Identification and surveillance of the areas potentially affected and timely deployment of fire fighting resources to the right locations are crucial elements in a successful fire prevention and fighting program. If such fires break out near inhabited areas, the additional problem of rescue and evacuation adds even more pressure to the situation.

3 POLYDROM is a transportation model developed by Systems Consult, Bern

This operation combines existing graphic data with objects describing the essential information necessary to satisfy the given surveillance and/or fire fighting objectives, superimposed onto scanned maps. The system used for this purpose is HyperBird®, which manages scanned map backgrounds and objects such as mobile vehicles, buildings or swimming pools. Depending on the requirements, the roads can be input into the system as well as a terrain model. The multi-media inputs/outputs allow the combination of remote measures, video inputs, screen, paper, and telephone output.

2.1 Implementation In The South Of France (1992-1993)

In the southern French region Bouches-du-Rhône the area of operation and surveillance was sized and defined. Large scale maps covering the entire area, and smaller scale maps, with detailed topographical information, were scanned and entered as background information into the database of HyperBird®. The area of surveillance was then divided into zones. Combustion characteristics and flammability of the vegetation in each zone were also added to the database. Together with wind data, this determines the extent of the different zones in danger.

Information about buildings and residences such as, locations, telephone numbers and the existence of swimming pools equipped with motor pumps also became part of the database.

Fire-fighting vehicles were equipped with Global Positioning System (GPS) satellite receivers/transmitters in order to be tracked and their geographic positions pinpointed and displayed by HyperBird® (figure 5).

Voice messages were prerecorded and included in the database. These messages cover different scenarios, and are to be broadcast in case of emergencies to individuals or organizations by a separate program that communicates with HyperBird®.

2.2 Operations

When firemen at monitoring stations are informed of an outbreak of fire by scouts, they can use HyperBird® to determine the zones of progress of the fire according to wind speed and wind direction. HyperBird® can also employ its database of combustion characteristics and flammability of the vegetation to predict the extent of the fire and the different zones in danger. Figure 1 shows the visual output of these calculations.

The application telephones inhabitants of threatened buildings and residences in priority order based on the degree of threat. It relays a prerecorded message to the inhabitants according to their situation. Residents in dwellings with swimming pools equipped with pumps can also be informed about actions to be taken.

The operators responsible for coordinating the fighting of an incident, monitor the progress directly on video terminals. HyperBird® controls three screens simultaneously in order to facilitate supervision of interventions. The information displayed is:

- Screen 1: The control panel or file information.
- Screen 2: A large scale color map to coordinate the overall intervention.
- Screen 3: Detailed information about known resources and risks (swimming pools with motor pumps, water reservoirs, surveillance vehicles, fire trucks, schools, hospitals, etc.) projected onto a color map (scale 1:25,000). This map may be replaced by an aerial photo that indicates detailed topography and the ground coverage.

Information from aerial photos can be complemented by other photographic data, or even recorded or real time films can be accessed via QuickTime™ within the object files concerned.

The operators can determine zones affected and the time required for interventions from the available data such as, the fire front and the positions of fire trucks or rescue vehicles. They can guide the vehicles to their destinations even through areas obscured by smoke. They inform the drivers of the routes to take between their current location and their target site, by monitoring the positions on the 1:25,000 scale map displayed on screen 3.

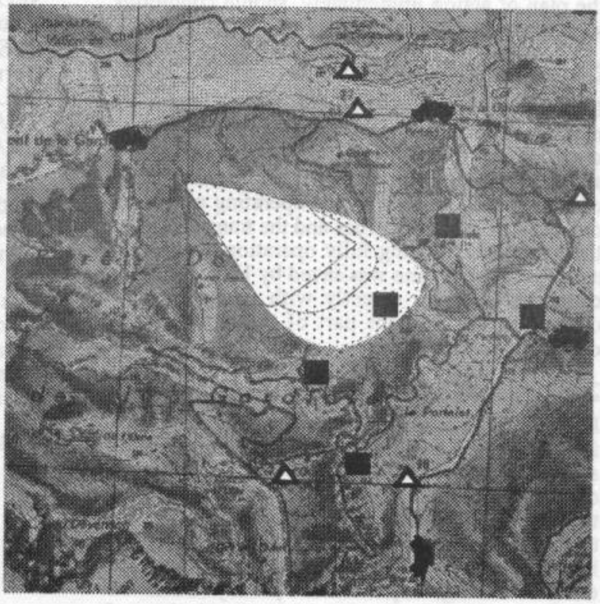

Figure 6

HyperBird® application for the surveillance of incidents in the South of France. Propagation model of fire - Location of fire trucks and dwellings with pools.

2.3 Benefits

Clearly, the actual forest fires are ultimately put out by fire fighters. No high tech system will replace this part of the mission. But fire prevention as well as fighting can be greatly assisted by a system such as HyperBird®. It significantly improves the logistics and the effectiveness of interventions. It cannot only better guide fire trucks and rescue vehicles to the most critical destinations but also guide them out of danger areas, thus greatly improving the safety of fire fighters. By letting the system communicate with residents in potential danger zones, the operators can focus on the task of minimizing the spread of a forest fire. The system lets them select optimal intervention areas. Once an area is secured, personnel and equipment can quickly be redeployed to another strategic location. The system also lets the operators change the plan of action immediately, should conditions such as, wind direction change.

2.4 Implementation Time Frame

Implementation was accomplished in about 12 months. Some extensions to HyperBird® were made during this time and are now a part of the standard product. Because of the user friendliness of the system, training of the operating personnel did not pose any difficulties and the transition from the test phase to being fully operational was very smooth. A lot of time was saved by Hyper Bird®'s capability to work directly with scanned maps, circumventing a major part of the cumbersome digitizing process.

2.5 Financial Considerations

Payback for this investment in high technology is a function of the frequencies of forest fires and the areas affected. At current timber prices, a reduction of the burnt area by less than a hundred acres over the lifetime of such an installation already pays for the incremental investment. Potential saving of human lives, and of livestock through improved early warning capabilities justify such an installation in many areas. Reduction in loss of property will not only benefit those affected directly, but the entire area through reduction of insurance rates.

3 CONCLUSION

The two examples highlight the possibility of developing scientifically advanced applications or, more directly, those centered around real-time management of buildings and infrastructures. They contribute towards materializing the urbistic concept which allows the use of geo-addressed data to be employed within a system of better resource management, using simple methods which also exploit numerical databases presently being collected as well as graphic documents which are already available for numerous applications.

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KEY CONSIDERATIONS FOR EMERGENCY RESPONSE COMPUTER SYSTEMS IN THE 1990s

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ABSTRACT

Recent advances in computer technology, together with analyses of several recent disaster responses, indicate that emergency management computer support systems can achieve much higher levels of usefulness than has been possible in the past. An emergency response computer support system can assist government officials in planning for, responding to, and recovering from hurricanes, floods, earthquakes, oil spills, hazardous materials accidents, and other emergencies. Key requirements include a fully integrated, Geographic Information System (GIS)-based computer system; functional support for each phase of the emergency cycle; and a fully developed operations concept. Keys to operational success include the ability to integrate the system with normal office procedures, the ability to share map and attribute data between agencies, full and continuous exchange of information between all parties, and organizational engineering to insure the maximum alignment between the computer functions and organizational units.

INTRODUCTION

Hurricanes, floods, earthquakes, oil spills, hazardous materials accidents, and terrorism have caused billions of dollars of property damage in the United States within the past decade. Recent disasters have shown State and local governments' need to improve emergency response services to respond to natural and man-made disasters. The public demands their governments provide, and often improve, emergency response services despite general cutbacks in budgets and personnel.

Several recently published documents, taken together, give remarkably good insight into the emergency management functions needed by local, municipal and State governments now and in the future [1,2,3,4]. Coupled with recent advances in computer technology and integrated into the fabric of the daily activities of the government organization, an emergency response computer support system can assist government officials in planning for, responding to, and recovering from hurricanes, floods, earthquakes, oil spills, hazardous materials accidents, and other emergencies. We propose that the lessons from these recent disasters, combined with emerging technological capabilities, yield key considerations or design criteria that emergency response computer systems must take into account.

These key considerations include a computer support system which should be fully integrated, GIS-based, with a fully developed emergency management operations concept, and support for each phase of the emergency management cycle. The remainder of this paper addresses these three key areas: technology, operations concept, and emergency management cycle support functions.

TECHNOLOGY

Let's examine the first of these key considerations: technology. The continuing explosion in personal computers and client/server and network technology, as well as related advances in GIS, databases, and Graphical User Interfaces (GUIs), can now provide a powerful, fully integrated emergency management system.

A system often consists of computer and data communications hardware, as well as software for the operating system, data communications, applications, user interface, GIS, and database management system. The system itself can be supported by computers of various manufactures and types, in a distributed configuration, possibly including a client/server system [5].

In addition to hardware and software, a system requires the collection of often extensive amounts of spatial and nonspatial data that describe the local sites and service areas for a region or state. These data can now be accessed as one logical database, with both spatial and attribute components.

High-end commercial GIS's now have the capability for full customization, including system-level and user-level tailoring. These characteristics support a software architecture where the GIS as well as the database, emergency alert modules, and other applications are completely transparent, allowing emergency analysts to concentrate on responding to the disaster, not trying to determine how the system operates.

Finally, with windows environments, the emergency responder has one GUI for all systemwide information tools and applications, making it very easy to access needed data for decision making.

OPERATIONS CONCEPT

The second key consideration we want to address in this paper is the operations concept. Recent work in emergency management and recently published disaster analyses have reinforced the necessity of having a fully-developed operations concept as the basis for the design of any emergency management computer system. This operations concept takes into account the data model, the required interfaces to the emergency alert system, and the necessity for precomputed actions. Additional considerations include a seamless map base, a continuous exchange of information among all parties, use of the system in daily operations, and a system carefully designed to be a component of the fabric of the organization.

Data Sharing

A typical system uses data collected by agencies such as public safety, transportation, environmental protection, natural resources, public works, and health. A shared data model between different agencies enables emergency management personnel to use the most current data available and reduces the amount of money an organization has to pay to build or maintain the system. Such a system will have many users trying to access the data at once, and requires record locking and data integrity capabilities.

Emergency Alert System Interface

An emergency alert system can consist of fixed sirens, radio and television, mobile loudspeakers, personal notification, personal pagers, and automated phone dialing systems. A computer support system with a database of key people and organizations and their telephone numbers can be interfaced to an automated phone dial system, greatly enhancing and reinforcing notification of various categories and types of emergencies. When coupled to the precomputed actions database, the automated phone dialing interface allows the system to exactly target only those individuals directly involved in the current disaster.

Daily Operations

An important part of the operations concept is using the system for daily operations as well as emergencies. This implies that office automation functions such as word processing, spread sheet, E-mail, desktop publishing, and project scheduling be fully integrated with database access, automated phone dial-up, precomputed actions databases, key geocoded MIS databases, and the spatial database and GIS functions. In this manner operators can insure that emergency databases are as up-to-date as possible. It also implies that simulation scenarios and other such databases be sized and constructed directly as part of the computer system to provide for frequent training of emergency management personnel. This parameter also reinforces the global user-view criteria, mentioned earlier, that one GUI be used for all systemwide information tools and applications.

Precomputed Actions

In an emergency such as a toxic cloud, chemical spill, or earthquake, there is no time for any planning whatsoever. Seconds count. Thus initial responses should be based on scenario-based, precomputed actions. A capable computer support system is essential in this case to the response, as there may be as many as 70 to 100 precomputed actions in the database to choose from, as well as an extensive hierarchy of Emergency Implementation Procedures (EIPs) (Standard Operating Procedures) that can be accessed and executed as necessary. These EIPs can be based on not only the type of emergency, but also its phase (planning, response, recovery) and the organizational function being performed by the analyst (operational, logistic, public affairs).

Continuous Information Exchange

Another important part of the operations concept is the necessity of insuring full and continuous exchange of information among all parties during all phases of the emergency. It is important not only that police know of the current location of rescue crews in earthquake rubble, but that everyone is quickly made aware of the fact that the building in question housed a medical radiology laboratory, and that there may be a radiation hazard for rescue workers. In a rapidly developing fluid emergency situation, ad hoc queries may be the norm, as analysts and directors attempt to stabilize the situation. The implications of full and continuous information exchange for the computer support system are that large numbers of ad hoc data queries can be expected, and that key MIS databases, which preexist the emergency support system, must be geocoded and integrated into the system.

Map Displays

The map displays and their related spatial databases are the key reference documents around which the entire emergency management operation is focused. With multiple disasters possible at various locations and covering various geographic extents, it is important to have map displays of variable scales so that the appropriate levels of detail for the emergency in question are displayed. For the computer system this implies that to the user there be a seamless database: an unbroken map display automatically unfolding as, for example, a gas plume wafts northeastward past the edge of the computer display. This seamless database is especially important in times of multiple emergencies in the same general area; the user must not have to figure out what map sheets are needed next.

Organizational Alignment

One aspect of the environment which is being recognized as increasingly important is the organizational context within which the emergency management computer support system operates. In emergency management, often the breakdown of tasks between personnel or even organizations within the same government entity has evolved on an ad hoc basis. This often results in inefficiencies which, if not corrected, end up being locked in stone in the computer support system. The entire field of business process reengineering, or in a government context, organizational reengineering, addresses this situation. The idea is to automate procedures in a way that represents an efficient organizational breakdown of functions.

EMERGENCY MANAGEMENT CYCLE SUPPORT FUNCTIONS

The third set of key considerations this paper will address for computer support systems is that support functions specific to each phase of the emergency management cycle are required: planning, response, and recovery. The following section highlights functional requirements by phases of the emergency management cycle. No attempt has been made to include all possible requirements, as they are jurisdiction-dependent. Instead, a sampling of functions that generally would be required for any disaster has been included.

Emergency Planning Functions

Planning and analysis modules are used well before the onset of an emergency. This is because the rapid onset of an incident often allows little to no time for planning. The planning and analysis modules are designed to determine three things: the sizes, shapes, and distances of the emergency response area; corrective actions; and the traffic flows and times for evacuation from designated areas in case of a major fire or toxic release.

Detecting and Scaling the Severity of a Potential Disaster. The system should show Emergency Operations Center (EOC) locations for all levels of government, as well as the impact the disaster will have on the following: population and housing, vital resources including transportation, and the environment. The system should also show the population at risk, the housing and other structures at risk, geographic areas that will be effected by an imminent disaster, and the potential environmental impact. As an example the system should show not only how a rail disaster affects rail traffic, but how the disaster will affect the entire transportation system in and throughout the region.

Evacuating and Sheltering the Public. Another important planning (and operational) function is evacuation and public shelters. The system should assist Emergency Response teams to determine potential evacuation routes due to an imminent disaster. In addition, the system should query the spatial database and the text database to show which large scale evacuation shelters to use and where the shelters are located. Road data and aerial imagery should be used to help locate potential tent city sites.

Activating the Response Plan. Activating the response plan is a crucial function of the computer system. Thus, the appropriate telephone auto-dial database is activated, the appropriate EIP identified, and to as great an extent as possible, the execution of the plan is begun automatically. The system should also assist with mobilizing and prepositioning resources, predetermining the location of medical services, sanitation equipment, and food stores and other staples.

The system should indicate the amount of resources required and where to preposition them, as well as determine the amount of resources required based on population density. This includes determining the optimal locations for positioning medical services, sanitation equipment, food and other staples, and temporary State or local Emergency Management offices.

The system should also have the capability to continuously provide the status of the Chain of Command, so that location of key members can be queried and displayed.

Delivering Immediate Emergency Response Services

Response and operations modules are used to alert appropriate authorities and responsible individuals, to keep users informed immediately after an accident, and to track progress as the procedures for dealing with the emergency are being executed.

Gaining Access to the Disaster Site. The system should identify all major and minor roads going into, out of, and through the disaster area, as well as those presently open for use by emergency relief, those that need to be cleared immediately, and those blocked by police or as a result of the disaster.

The system should be able to identify the company or organization responsible for clearing or removing debris from the roads and for restoring traffic signals using a situation map of the area and polygon overlays. The amount of equipment available to each organization must also be identifiable. All airports and railway lines providing service into, out of, and through the disaster area should also be identified.

Coordinating Transportation Requirements. The system should be able to record vehicles available for emergency transportation and prioritize and allocate available transportation. The system should be able to track hazardous material and hazardous material-related transportation problems, as well as funding to make emergency highway repairs and reopen inoperable airports and railway lines.

Conducting Search and Rescue. The system should be able to record both the search and rescue assets available for support during an emergency and where these assets are needed. The system should also be able to record the location of damaged areas that have been inspected, and record the location and extent of fires.

Providing Medical Services. The system operator should be able to record the location of casualty clearing and staging sites as well as the personnel and resources available at each site. Medical services available for support during an emergency should also be tracked, and the need for replacing volunteers with full time personnel or other volunteers should be recorded. The system operator should be able to record the additional medical services needed to support an emergency as well as where these assets are needed. The location of specialized medical services such as burn treatment centers should be recorded and located.

Providing Mass Care. An emergency management analyst should be able to record the location of mass care sites as well as the personnel and resources available at each site, including volunteers and replacements. The system operator should be able to record additional mass care services available for support during an emergency, as well as record where additional mass care personnel and resources are needed.

Providing Security and Law Enforcement. A system should be able to record where additional security and law enforcement services are available for support during an emergency, as well as where they are needed. The system should record the plan for coordinating law enforcement assets in each region, the amount of law enforcement personnel and equipment available in each region, and the level of security required for each area. The system should record the plan for coordinating fire-fighting assets in each region, the amount of fire-fighting personnel and equipment available, and the level of fire fighting required for each area.

Providing Emergency Recovery Assistance to Victims

Recovery and reentry modules evaluate the accident, including its root causes; analyze possible noncompliance with State and local laws; keep users informed of the cleanup operations; and track progress as the emergency response and recovery procedures are implemented.

Understanding Assistance Programs Available. The system should provide a checklist that can be printed so a victim can determine which disaster relief programs are available to assist him or her. The system should be able to access information about how to apply for assistance programs available from public and private organizations.

Delivering Needed Assistance. The system should be able to record which victims have applied for assistance, and the amount and type of assistance from each Federal, State, or local program. In addition, the system should be able to record which victims have applied for property damage payments, and the amount and type of property damage payments that have been given to each victim from each program. The system should also be able to record a list of inspection contractors available to verify housing and personnel property losses, as well as a list of utility companies available to fix needed utilities damaged or destroyed during an emergency. The system should be able to record a list of victim complaints and the response to the complaints. Finally, the system should also be able to record a list of action items, their due date, their completion date, and how each action item was resolved.

CONCLUSIONS

This paper has highlighted some key considerations for municipal, State, and local governments when considering the purchase or upgrade of a computer support system to respond to large or small emergencies. Recent advances in technology and analysis of recent disasters from small- to large-scale point to the fact that fully integrated, GIS-based systems, with fully developed operations concepts and support for each phase of the emergency management cycle, can result in high payback for State and local governments and commercial enterprises.

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NATURAL HAZARDS AND EMERGENCY MANAGEMENT

DECISION SUPPORT SYSTEM IN VARIOUS EMERGENCY CASES

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ABSTRACT

The problems and difficulties are considered regarding the use of information on the state of natural environment under decision-making. A research variant of DSS is given. There are possibilities of introducing mathematical models in the system for specifying impacts, recommendations and also graphical means of information display, which enable one to envision the given situation more illustratively. It is proposed that this system should be used in disaster situations and various types of emergencies. The mechanism available in the system makes it possible to use within one environment the sub-system of most various orientation (flood, environmental pollution, et al.).

1. INTRODUCTION

Efficiency increase of the use of information on emergency cases is already impossible without automatization and making information promptly available to the heads for decision-making. Throughout implementation of PC computers enables decision maker to regularly apply computers in making a choice and underlying grounds for taking measures. The best known way of organizing an assistance to decision-maker at present is Decision Support System (DSS).

An account of Emergency cases at mills is an important part of the work of managers (decision-makers), especially in such fields as, ecological disasters, fires, etc. A number of mills which are affected by Emergency cases and their diversity as to the importance and the needed information type (current, forecasting, climatic and past weather) require not only general recommendations but quite specific indices of Emergency effects on plants as well as specific recommendations for mitigation or prevention of these effects.

2. DSS FOR EMERGENCY CASES

With a view to computerizing the preparation of decision, classification of impacts on industry objects and actions on their decreasing and preventing it is proposed to develop the decision support system to produce recommendations under different values of environmental parameters.

The following consideration is underlying in the approach to the creation of DSS. With criteria of emergency cases known before, it is possible to determine the list of impacts on objects of industry and population. Having determined the impacts it is also possible to work out recommendations for decreasing or preventing these impacts.

For creating the system the «shell» of the expert system SPRINT originally developed in Russia is used. SPRINT enables creating simultaneously to about 250 diversely oriented subsystems. DSS for supporting the merchant marine ships and ecology can be given as examples.

The major principle in developing a DSS has been combining processes of creating message (effect) bases, bases of recommendations and knowledge as stages of individual process which gives the possibility of very quick debugging of the knowledge base. Associations between the values of the environment parameters and the messages are established in the form of logical conditions «if..., then...». To decrease the volume of the knowledge base and the time for preparing data on diskette the key words «if, then» are omitted.

The form of knowledge presentation, reflecting the impact of hydrometeorological phenomena on drilling rig is given below:

```
a1a  (wind)10,a1c,a1b
a1b  1,11
a1c  (ice)3,a1e,a1d
a1d  2
a1e  (ice)3,a1g,a1f
a1f  (temperature),a1g,a1l
a1g  (waves)5,a1k,a1h
a1h  4
a1k  15
a1l  3,7
```

A fragment of the message is given below :

1. Drift of vast ice fields consisting of large broken pieces of ice of different continuity.

2. Separate sets of ice formations emerge (icebreccia, ice floes of old ice fields).

3. Accumulation of broken ice get frozen as one unified field.

4. An intensive splash generating is observed. Urgent measures on drilling stoppage can hardly be taken.

5. Frazil and grease ice as well as snowsticking is observed on the construction.

6. Drill rig construction becomes covered with ice.

7. A space between drill pipe strings and floating hulls is blocked up with ice floes.

8. The repeated bumping of ice against the drilling rig is observed.

9. The construction of a drilling rig is subject to the ice dynamic attack.

10. The rig becomes icebounded.

11. The rig is moved along with ice.

12. The rig vibration develops. A danger of resonance emergence can take place.

The respective recommendations have the following form :

1. To carry out operations to move from the point.

2. To choose the way of transportation.

3. To determine the number and location of towing vessels.

4. To keep unmoored floating submerged drilling rigs in the drifting ice.

5. To choose the way of eliminating an emergency.

6. To provide a crew with efficient rescue facilities.

7. To prevent an oil spreading.

8. To tow the torn off drilling rig.

9. To evacuate a crew.

The list of impacts and recommendations may be continued and changed during the creation and development of the system.

There is a specific list of messages for each current, forecast, climatic or past weather value of the environment parameters. The set of messages is also different for different management levels. The list of messages also depends on the type of measures (tactical, strategic, current) to be taken, the season of the year and the objective. A specific recommendation corresponds to each message.

Basing on the created subsystems one can develop trainer to explain the rules of behaviour to students and leaders in cases when natural environment changes. The idea which lays behind is the following. Under DSS development the proper data and knowledge bases are created which include information on impact of natural environment on man, medium and plants as well as recommendations for decision - making to decrease or prevent this impact. After the diagnosis is made the user gets the lists enumerating all impacts and recommendations which correspond to the given conditions. Including additional records, containing wrong messages and recommendations in the above lists, the system makes the «pupil» to choose right recommendations. The chosen messages and recommendations are properly estimated. The objective pursued under development of such trainer is creation of data and knowledge bases for various emergencies.

The advantage of such an approach is the fact that data and knowledge bases are developed first for DSS and then already applied for trainers. As DSS develops for emergency cases the trainers should also be improved.

DSS must interact both with acquisition systems (for obtaining current information on the state of nature) and the data banks «orecast» (obtaining prognostic information) and «Climate» (obtaining climatic information).

In addition to semantic description (what is going on and what should be done on the object) DSS has possibilities to specify the impacts and recommendations at the registration of utilizing the specific characteristics of the object. Some proper mathematical models (economical, optimizing, etc.) are applied with the above in mind. The list of the models which have been realized using PC is rather large. Many of them can be included in DSS without being modified.

DSS enables one to utilize these models both as own computer means on the level of communication systems and being included in DSS after specifying the impacts on the object, population and recommendations with reference to the specific characteristics of plant.

Due to the fact that, the volume of the semantic description of situations is rather large sometimes, a part of reference information (terms, detailed information and/or recommendations, etc.) may be localized in corresponding files, which would be called on DSS demand only.

Graphic presentation of information about object, technological processes, environmental area, etc., would be useful information. Consequently cartographic information must be included in DSS.

The system SPRINT makes it possible to produce simultaneously up to 1000 subsystems of different orientation, scattered over seven subject areas. Such a system can be elaborated for administration of the towns, heads of large enterprises situated in the regions subject to natural disasters.

DSS plays the role of advisor in decision-making using information on the state of natural environment, it makes more complete and qualitative the produced recommendations for accounting the impacts on objects. This system will help decision-makers and leaders of the enterprises to make plans of measures before, during and after the disaster occurred.

At present above 50 subsystems are at various stage of their realization. The following systems are most complete:

Vessel —allows the captain and navigator to get recommendations for decision-making in different hydrometeorological conditions.

Flood —is designed for determining the impacts of flood on population and industry objects, situated in the flooded area, and producing recommendations for taking preventive measures.

Ecology — allows to determine the impact of natural environment on population and produce recommendations for decreasing this impact.

DSS is designed for wider application, hence it is possible to develop additionally subsystems for making consultative assistance to the leaders (e.g. in case of emergencies and disasters, etc.) when creating the specific variants of the system to order. This variant of the system is presented more with details in the article, Vyazilov (1991).

3. CONCLUSION

DSS will be of great help in making the plans of actions on accounting hydrometeorological conditions. DSS can be relied upon, if it is necessary to:

— develop long — term plan of actions on accounting hydrometeorological phenomena and other emergencies;

— work in environmental conditions and far from scientific centers;

— assess to the full extent safety measures taken against disasters;

— organize teaching of leaders to safety measures to prevent losses from hydrometeorological phenomena;

— work out plan of actions for considering current, prognostic and climatic values of hydrometeoparameters.

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SPATIAL KNOWLEDGE BASE FOR NATURAL HAZARD PROTECTION : THE ARSEN PROJECT

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Abstract

The development of a decision support system dedicated to a specific natural hazard requires a good representation of spatial knowledge : geometrical objects and spatial processes have to be taken into account for the construction of such a system. Several systems have been developed in France recently for different natural hazards : snow avalanches, slopes stability, forest fires, snowdrifts, torrential floods... For each of these applications, the representation of space has been studied and implemented separately in a different manner.

The aim of ARSEN project is to take advantages of this experience to build a kernel of spatial objects and methods which could be used as a generic tool. It will be integrated in future systems to organize and manipulate spatial knowledge in order to get a simulation of natural hazards and face real-time crises.

In a first part, this paper gives a few samples of objects and processing methods used in the already existing systems. We lay emphasis on the analogy between these different applications. After this analysis of the spatial representation requirements, we suggest a definition of the kernel of ARSEN. In a third part, we describe the way in which ARSEN is implemented. Finally, we present an application where the kernel of ARSEN is used to take into account rock falls and snow avalanches.

1. Introduction

Protecting human beings and their equipments against natural hazards has always been a great preoccupation in people's mind. The first thing people do is to study the phenomenon, and try to understand the way it functions.

Then, the experts often try to simulate the comportment of that natural hazard by employing models, in order to protect dangerous zones from disasters. These simulations, using the help of computers, need a spatial representation of the studied terrain. This paper presents a generic tool aimed at helping designers in obtaining that representation, and its possible applications.

2. Spatial representation in existing systems

The development of an expert system dealing with a natural hazard needs a good spatial representation. The aim of that representation is to apply numerical models or expert methods. Here are some examples of such developments.

ELSA [Buisson 93]

This system is dedicated to avalanche path analysis. It specially studies the starting zone of avalanches. To apply a reasonning of expert, ELSA needs a tesselation of that zone in elementary areas called "small panels". These small panels are considered homogenous for parameters such as slope, type of vegetation...

According to the designers of ELSA, programming that spatial representation was a very long and hard part of the development. And now, as these designers want to improve ELSA by adding new models, others representations are required, so another period of tiresome programming is supposed to begin.

ETCBC [Jover 93]

This knowledge based system studies the phenomenon of torrential floods. The aim of the spatial representation is to apply the ETC model, that works with spatial entities such as watersheds and reachs. These spatial entities are obtained by entering some polylines (boundaries of slope basins, thalwegs...) and extracting from this information the polygons and polylines used by ETC model.

With a rainfall simulation, the program gives the rate of flow in each reach, so the user can predict floods and act to avoid them.

XPENT [Faure 92]

The aim of this expert system is to study slope stability, in order to suggest technical solutions. The requirements in spatial knowledge consist in getting soil sections to apply expert reasonning on the differents layers.

The input spatial data of a slope stability study are often ponctual informations given by drillings. Other informations are obtained from a terrain expert who enters some specific objects such as springs, torrents, rifts...

The program must organise this spatial knowledge to be able to give the right soil sections.

πR3D [Tartivel 93]

This program was developped to simulate rock falls. To apply a simple numerical model based on bouncing onto triangle surfaces, πR3D needs a spatial representation based on a regular grid with an elevation at each intersection.

To apply πR3D to a real rock fall path, the easiest way is to buy a digital elevation model (DEM). But in many cases those DEM are not available, so the user has to create his own DEM with, for example, a digitized map on which he notes some points with their elevation. After a triangulation of those points, altitude can be calculated everywhere with a linear interpolation.

For each of these developments, the creation of the right spatial representation is a tedious programming task. The designers often waste their time in building that representation. Moreover, a lot of common tasks have to be developped separately : getting some objects (points, lines, areas) on screen, triangulations, interpolations...

There are lots of tools dedicated to help designers, such as automatic tesselators and geographic information systems (GIS). But the general drawback of these tools is a real problem of integration. For example, creating a spatial representation may be done through a series of file transfers, because that creation needs a GIS on a Unix work-station and a tesselator on a PC machine. If the aim of the study is to consider two or three examples a year, this is an acceptable drawback. But in an engineering context, facing real time crises or a lot of problems, the rapidity is very important, and those manipulations are unacceptable.

So there are some well determined needs in spatial representation, especially in integration of classic methods and objects with numerical or empirical models.

3. The ARSEN project

This project gives a solution to the requirements of the first part. ARSEN is a kernel of spatial objects and methods, constructed to be used as a generic tool. It is designed in order to help designers to get easily the spatial representation they need.

In this paper, the word **designer** is used to represent the person who uses ARSEN, and the word **user** mentions a person who uses the application developped thanks to ARSEN. The following figure explains the position of the user and the designer.

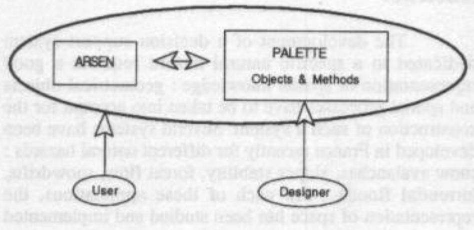

Figure 1 : General Architecture of ARSEN

The "palette" is the structure defined by the designer, in which the specifications of the application are included. For example, in an application concerning snowdrift, this palette should contain specified objects such as ridges and snow fences, and methods such as a simulation of snow falls. Then, when the development of the application is finished, the user can load the palette defined by the designer , in order to use it to obtain the spatial representation of the terrain he studies.

To be useful, ARSEN needs a good organisation of spatial knowledge to cope with the requirements of models. These data are organised in three layers, in order to get a complete description of the terrain :

- a geometric layer, including parameters such as x,y coordinates, length of segments, area of triangles.
- a vectorial topological layer, following the GIS model, to include knowledge such as neighborhood of faces.
- a user layer, corresponding to the requirements of natural hazard studies. The spatial knowledge is organised in point, line and area objects, with the possibility of mixing some of those simple objects in a complex object (like a coverage).

The following figure 2 explains that organisation. The user layer is the only one visible by the user. The other layers are transparent to him. But the designer may act on each layer, which gives him the ability of implementing his own procedures (for instance a special triangulation) on the objects he wants. This specificity distinguishes ARSEN from a classic GIS, where dealing with the geometric layer is often impossible.

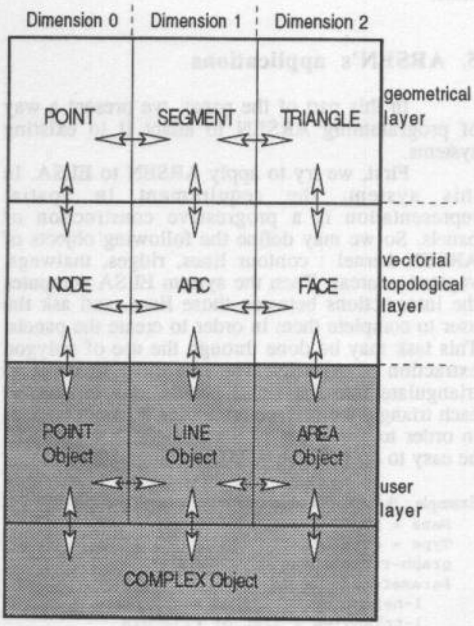

Figure 2: The Spatial Knowledge Organisation

The multiple arrows are representing the dynamic relations between the elements of the layers. For example, if we consider an arc, it has a beginning and an end node, a list of segments composing it, a right and a left face, and a linear object in which it is included.

When the user data are defined, different methods have to be employed to fill the layers. At the beginning, we suppose we have a domain of study (a polygon), and some point, line and area objects given by the user. At this step the user layer is complete.

The first thing ARSEN has to do is to fill the vectorial topological layer. One of the constraint of that layer is that two arcs can't intersect. So if two line objects are intersecting, a node has to be created to respect GIS rules. A decomposition in faces is also required, so that operation is called "polygon extraction". The figure 3 explains that operation.

The next operation consists in filling the geometrical layer. To have a complete description, we need a decomposition in triangles of each face. So this second general operation is a triangulation, also shown in figure 3.

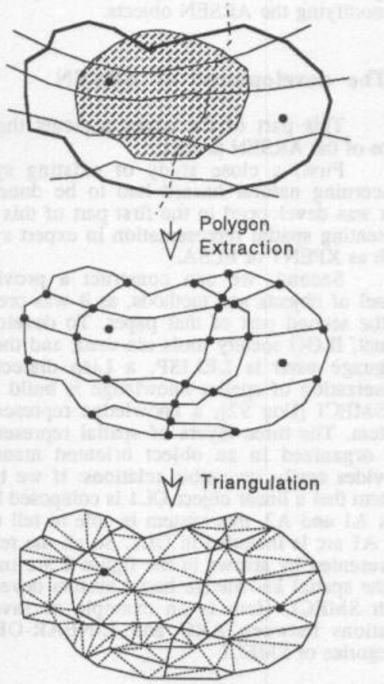

Figure 3 : Filling the layers

The domain of study is within the thick line, there are five line objects, two point objects and one area object. The polygon extraction calculates the intersections between the user lines, and erases the part of objects outside of the domain. Then the triangulation constructs the segments and triangles to complete the data structure.

As the construction is complete, some methods are easily applicable. For example, if the value of a parameter is known for each point of the representation, it is possible to know the values of that parameter everywhere, with a linear interpolation in the triangles.

The general idea of the ARSEN project is to create a tool that designers can easily adapt to their own problems. They should be able to define their own objects (such as ridges, forest areas, drillings...), and to implement their own methods dealing with these objects. For the designers, the access to the data structure has to be quite easy, in order to help them in customizing the system. For instance, if the model they want to apply needs a triangulation where the circularity of triangles (ratio : perimeter^2 / area) is under 40, they can program that special triangulation using, creating or modifying the ARSEN objects.

4. The development of ARSEN

This part of the paper presents the main steps of the ARSEN project.

First, a close study of existing systems concerning natural hazard had to be done. This part was developped in the first part of this paper, presenting spatial representation in expert systems such as XPENT or ELSA.

Second, we can construct a provisional kernel of objects and methods, as it was presented in the second part of that paper. To develop that kernel, ILOG society tools are used, and the main language used is LELISP, a Lisp dialect. The organization of spatial knowledge is build thanks to SMECI [Ilog 92], a knowledge representation system. The three layers of spatial representation are organized in an object oriented manner. It provides easily inversible relations: if we tell the system that a linear object OL1 is composed by two arcs A1 and A2, this system is able to tell us that the A1 arc is included in OL1. So all the relations represented by arrows in the figure 2 are included in the spatial knowledge based system developped with SMECI. Here is an example of inversible relations between ARC and LINEAR-OBJECT categories of SMECI.

Details about the slot l-linear-objects of category ARC:

```
Name = l-linear-objects
Type = list of linear-objects
Inverse = l-arcs
```

Details about the slot l-arcs of category LINEAR-OBJECT:

```
Name = l-arcs
Type = list of arcs
Inverse = l-linear-objects
```

There is also a need in graphic tools to develop an user friendly and rapid interface for ARSEN. That part of the project is developped with MASAI-2D [Ilog 93], an interesting tool which can deal with a lot of graphic objects on screen, using a quadtree structure to store the geometric data. That second part of the development of ARSEN is currently engaged.

In a third part, there will be some tests on existing systems, such as those already studied in the first part of this paper. The aim of that part of the development is to improve ARSEN by applying it to existing systems.

After this phase of improvement, ARSEN will be distributed to others designers of environmental studies, in order to test it on a large scale.

5. ARSEN's applications

In this part of the paper, we present a way of programming ARSEN to adapt it to existing systems.

First, we try to apply ARSEN to ELSA. In this system, the requirement in spatial representation is a progressive construction of panels. So we may define the following objects of ARSEN kernel : contour lines, ridges, thalwegs, vegetation areas. Then the system ELSA computes the intersections between those lines, and ask the user to complete them in order to create the panels. This task may be done through the use of polygon extraction of ARSEN. The last thing to do is to triangulate into the small panels, and to give to each triangle the surface properties it has to possess in order to apply the ELSA model. That part will be easy to do with the ARSEN triangulation.

Example : the ARSEN object defining a small panel.

```
Name = small-panel
Type = area-object
graph-representation = bundle*
Parameters =
   l-neighbors = list of small-panel
   l-triangles = list of triangle
   nearest-ridge = ridge
   distance-to-ridge = real number
   slope = method
   surface = method
```

*** : a bundle is a structure of MASAI-2D that specifies the color, the type of line, the priority of display... of an object on screen.**

The second example we shall present is the πR3D system. The aim of the representation is to get the altitude on each intersection of a regular grid. The user's objects of ARSEN may be ridges, thalwegs, points where the altitude is given (reading a map or making a field measure). There is also a need in expressing the nature of the surface by including area objects in the ARSEN representation. By completing the other layers of the input data, we have a complete representation of the terrain that can be interpolated through the triangles in order to obtain the grid. This interpolation may be done with ARSEN (a linear one is to be implemented) or the designer of πR3D model can program his own one. The idea of

ARSEN is to provide an easy integration of such a specialized development for a special model.

These two examples, the implementation of which is not done yet, may help us in improving ARSEN.

6. Conclusion

At the current state of development of ARSEN, it is not possible to affirm that this kernel of objects and methods is a good solution to help designers yet, in order to obtain the right spatial representation they need to apply their models. But the ideas presented here are useful, and may help a lot of persons who develop natural hazard studying systems.

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- CNRS, Environment program.

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FOREST FIRE DANGER ASSESSMENT : COMBINATION OF METHODS FOR EFFICIENT DECISION MAKING

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Abstract

Forest fires danger is one of the main emergencies in many countries all over the world. To reduce the consequences of their occurrences, forest managers or fire officers use prevention, by reducing biomass, by locating fighting teams in exposed areas or by patrolling. To fight efficiently, they use suitable means: trucks, planes, helicopters, fire retardants. The keypoint of prevention and fighting is the assessment of danger, which can be done from different points of view and at different time scales: from historical data, real time monitoring or forecasting.

This paper describes a combination of assessment methods, integrated in a decision aid system. Four methods are used, related to: inflammability of dead fuels and live fuels, which assess the behaviour after ignition, fireline intensity, which assess the difficulty of fighting and fire occurrence, which assess the frequency of fires from historical data. The integration of these methods is done using a knowledge-based approach, in association with a relational database and a GIS (Geographic Information System).

Finally, we present some results obtained on the test region of Mount Parnis, near Athens in Greece.

Keywords

Forest fires, Danger assessment, Decision support, Expert system, GIS (Geographic Information System).

1. Fire Danger Rating methods : literature review

The most commonly used definition of Fire Danger is the resultant often expressed as an index of both constant (fuel types, topography ...) and variable (weather conditions) danger factors which affect the ignition, spread and difficulty of control of fires and the damage they cause (Chandler et al 83).

Several countries have at different times set up various methods for forecasting the fire danger rating (Chandler et al 83), starting from a number of different assumptions, even though these have in general been based essentially on the consideration of meteorological factors. A synthesis of the main methods adopted and their particular structure is briefly presented.

All these systems developed in various countries, although varying in appearance and complexity, have the common objective of obtaining a relatively simple and comparable measure of the inflammability of forest fuels from day to day.

The US method (The NFDRS, The National Fire Danger Rating System), is based on the mathematics and physics of fuel moisture and heat exchange as they affect fuel moisture variations (Deeming et al 72) and on laboratory experiments about the influence of various fuel and weather factors on fire behaviour (Rothermel 72). The NFDRS interprets the moisture level of a wide range of forest fuel sizes through the use of three representative classes of fuels with different drying states. It includes a fire rate of spread component and a component to represent the effect of long-term drying on the fuel. It also produces an index representing the fire intensity (BI, Burning Index) and it has a number of other indexes that can be used to indicate the level of other fire factors such as ignition possibility or rate of spread.

The Canadian method was largely developed from statistical analysis of large quantities of field data. The tables were empirically constructed by putting together weather, fuel moisture and fire behaviour data (provided by small test fires). Van Wagner describes this method (Van Wagner 74) which has been implemented on a computer (Kourtz 80). The index is based on daily measurements of weather factors (wind speed, rainfall, temperature and relative humidity of the air) recorded at 12 a.m..

These authors consider that it is impossible to give a complete indication of fire danger rating for a given day only with one value. Based on the water content of three types of fuels, combined with the effect of the wind on the fire behaviour, this Fire Weather Index (FWI) is divided into six components:

. three primary sub-indexes representing the water content of a layer of forest bed and other light fuels (FFMC, Fine Fuel

Moisture Code), the water content of a layer of compact organic matter (DMC, Duff Moisture Code) and the water content of a deep layer of compact organic matter (DC, Drought Code);

. two intermediary sub-indexes representing the rate of spread (ISI, Initial Spread Index) and the total quantity of fuel available for combustion (BUI, BuildUp Index);

. a final index representing the amount of energy produced per time unit and length unit of the flame front (FWI, Fire Weather Index).

The originality of the American and Canadian works is that they take into account different parameters from different components: fuels factors, human factors and meteorological factors. These global approaches (including the most important danger parameters) result in a risk integration. On the contrary, the other methods presented below do not have this characteristic.

The Australian method was developed, as the Canadian one, from statistical analysis of large quantities of field data (McArthur 66 a et b). McArthur designed a meter based on fire behaviour data measured after some 800 test fires with typical fuels. The tabulated indices have been reduced to equations (Noble et al 80) and programmed for use on a pocket calculator (Crane 82). This method is based on the consideration of the following parameters:

- fuel water content and its daily variation
- both open field and inside the wood wind speed
- fire rate of spread
- fuel load and its relation with the rate of spread
- slope
- height of flame as a function of :
  fuel moisture content, fuel load and wind speed.

Two indices are calculated. The first one is a cumulative index (based on evapotranspiration, rainfall and air temperature) providing the degree of inflammability of the fuel . The second one is an index that determines the level of fire danger, the speed of propagation and the difficulty of extinguishing the fire, and has a closed scale ranging between 0 and 100.

In France, a method based on the major weather factors and on empirical equations derived from experimental studies is used (Sol 92). The estimation of the risk level is based on meteorological forecasting and the actual system, developed by the National Weather Service, includes weather parameters and soil water content. The risk level is described by five levels (low, moderate, medium, high, very high).

Two other methods are integrated in the Expergraph system (Wybo 92), one is proposed by Carrega (Carrega 90). The Carrega "85/90" index for fire generation and spreading, initially elaborated for the French Riviera, turned out to be applicable to the entire south of France where it was tested by the National Weather Service.

The formula is : $I = (500 - (H.\sqrt{R} / V).C) / 25$

where R is soil water reserve according to Thornwaite (saturated at 150 mm), H is the minimum air relative humidity in percentage, V is the wind speed in Beaufort degrees and C is a phenological coefficient of vegetation that ranges from 0.8 to 1. The "I85/90" index is defined as ranging from 0 to 20 (maximum risk). Thus, the fire hazard is low up to 8, moderate up to 14, severe up to 18 and very severe beyond this value.

The second method links, for each location, an estimation of the rate of spread with the time needed to reach it. These values are used to estimate the amount of burnt surface. This index gives an idea of the size of the fire that the firefighters will be facing.

In (ex) USSR, the most widely used method (Nesterov 49) is an index of fuel inflammability, which is a cumulative index calculated during the interval of days in which there has been no daily rainfall exceeding 2.5 mm.

Other approaches have started from the consideration of forecasting methods adopted in Canada and the USA, integrating and modifying them according to the different conditions of climate and vegetation prevailing in the respective countries. Other authors (Chuvieco 89) use a G.I.S. approach to take into account a danger index based on several parameters such as: slope, exposure, altitude and distance to road.

2. Knowledge based system coupled with a G.I.S. for wildfire danger assessment

The main aim of this study is to provide users with an efficient set of data to support their decisions for prevention and fighting of forest fires. We have decided, as it has been done in the methods reviewed above, to build several indexes rather than an integrated one, each of these indexes being representative of an aspect of danger.

2.1. EPOCH # 40 methods

The study of forest fire behaviour shows four steps:

- is there any reason for a source of energy to be present ? In other words, in each location, what is the probability for a fire start ?
- the starting point of fires is generally on the ground, as such, is the dead fuel on the ground dry enough to allow an extension of the initial energy ?
- once the dead fuel on the ground is burning, the fire will really expand if the live fuel is dry enough to burn and as such, increase the biomass involved and consequently the energy of the firefront.

- to estimate the difficulty of fighting, the most suitable index is the fireline intensity.

In the frame of project EPOCH # 40 (supported by the EEC) four fire indexes have been established in order to represent these four steps:

- the Fire occurrency
- the Average Inflammability of Dead Fuels
- the Average Inflammability of Live Fuels
- the Fire Severity

2.1.1. Fire occurrency

To estimate the spatial density of fires in an area, we use a list of fire events, giving their date and location. First, we fix the period of time for which the fire events are processed, for instance the last five years. Then, we calculate all the distances between fires, we sort the results in classes and we determine the more frequent class, which distance is used for integration.

The next step is to create a map (figure 1), giving for each pixel the density of fire events. For each event of the list, we create a circle centred on its location and which radius is the distance used for integration. Then, for all the pixels included in this circle, we add a constant to the current value.

2.1.2. Average Inflammability of Dead Fuels

The Average Inflammability of Dead Fuels is derived from the estimation of the thin fuels (1hr-timelag) moisture content, as they change under different meteorological conditions and during day and night hours. This index has also been considered as independent from the type of fuel model. Thus, this index has been estimated by the two following steps:

Step 1: estimate the fine fuel moisture content from tables as they have been proposed by Botehlo [1]. The relative humidity and the temperature during the day and night are the meteorological parameters which have been considered in these tables, on which are applied correction factors, according to the different hours of the day and night as well as for the amount of rainfall per week.

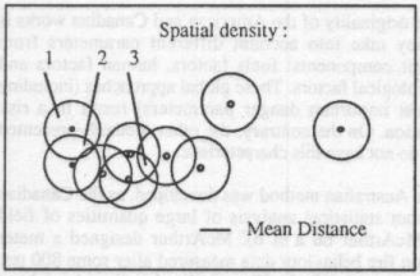

Figure 1 Fire occurrency computation

in these tables, on which are applied correction factors, according to the different hours of the day and night as well as for the amount of rainfall per week.

Step 2: classify the values of the fine fuel moisture content in terms of four average inflammability levels (Low, Medium, High, Very High).

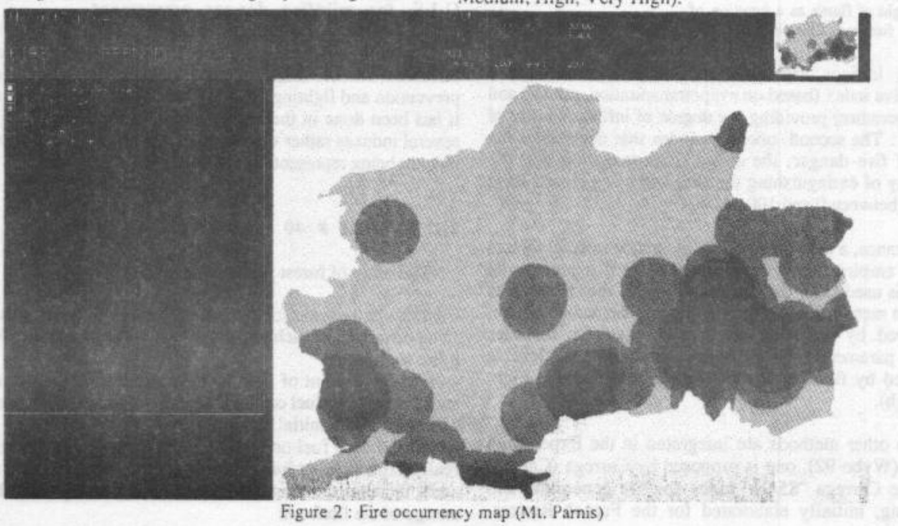

Figure 2 : Fire occurrency map (Mt. Parnis)

2.1.3. Average Inflammability of Live Fuels

The average inflammability of live fuels is derived from the estimation of the inflammability of live fuels of all the fuel models. The fuel models which are considered here are those represented in the Mt Parnis area, but this method can be extended to other models. The estimation of this danger index was done in four steps:

Step 1: Two inflammability indexes were given to each one of the understory species of the fuel types of Mont Parnis. These indexes express the inflammability level of species during summer, and more specifically the first one gives the inflammability level for the months May, June and July (early summer) and the second, for August, September and October .

The selection of these indexes was done by Valette (Valette et al 90) according to flammability studies done on species of southern France which are similar to those of Mount Parnis.

Step 2: The average inflammability index of each fuel model was estimated by the following way:

- evaluate the volume (coverage x cover) of each species,
- multiply the volume by the inflammability indexes (early / late summer),
- make the sum of all the species and thus one index corresponds to each fuel model.

Step 3: The number of classes and the class limits were determined according to the values of the fuel models indexes and also to the needs (of detailed estimation). Thus, four inflammability classes were created.

Step 4: Finally, each fuel was classified in terms of the average inflammability of its live fuels during summer period (early and late).

2.1.4. Fire Severity

The fireline intensity is the parameter considered for the Fire Severity estimation. The interpretation of this parameter is best related to the prediction of severe fire behaviour (Rothermel 83).

The steps to estimate this danger parameter were the following:

Step 1: Both fuels characteristics and meteorological parameters were considered. From the fuel models of Mt Parnis and the relative humidity and temperature, the fireline intensity was calculated as one of the outputs when applying Rothermel's model and especially BEHAVE equations, in order to predict the rate of spread without slope and wind effects.

Step 2: Four classes of fire severity have been created from the values of fireline intensity derived from the above calculations, based on the classification given by bibliography (Rothermel 83).

2.2. A knowledge based approach linked with a G.I.S. for fire assesment

Geographic Information Systems (G.I.S.) have a significant impact on the quality and the effectiveness of forest management. To plan and manage forest effectively, both accurate and appropriate data for modeling information is needed. In addition, this information must be easily maintained and updated to incorporate current information from a variety of sources. Current applications incorporating G.I.S. technology have clearly illustrated its importance and viability as a mechanism for improving program management and short-term decision making.

In order to increase the performances of a GIS we have linked this tool with an expert system. Thus, the Expertplan system (Wybo 91) is used to estimate the danger indexes. The knowledge formalism consist in production rules, wherein expert knowledge is expressed as a series of independent statements with each statement being encoded as an independent condition-conclusion pair. This formalism has proven to be the most commonly used declarative representation in operational expert systems.

After collecting knowledge and writing the corresponding set of rules (in a text file, using a small set of symbols), it is necessary to build a knowledge base which can be used for deductions. To do this, we have designed a rule compiler, which role is to verify the syntax of the rules and to build the knowledge base, containing parameters, rules and relations between them: which parameters are conditions in a rule, which rule conclude on a parameter.

Once a knowledge base has been designed and tested with EXPERTPLAN, it is necessary to describe (in database tables) the characteristics of the parameters: constant value or map, value, name of the map. It is also necessary to associate to each parameter which format is a map a set of classes. These classes represent all the possible values for a parameter. They are associated to colours for the display.

When all these specifications are ready, EXPERTCARTE (Wybo 91) a second expert system designed to manage raster maps (from the G.I.S.) assesses the Danger rating indexes presented above on maps. To achieve this task, the maps of input parameters (used in the deductions) have to be created in the G.I.S.

During a deduction session, EXPERTCARTE updates (pixel by pixel) the maps of the deduced parameters. After the deductions, all the output parameters which format is a map are updated, and their versions (date and time of update) are also updated in the database.

The main characteristics of this expert system are:

- data is represented as raster maps (one per parameter of the knowledge base),
- there is no direct interface with the user.
- it has the ability to interact with the Database Management System.

In fact, it receives the knowledge base name with which it shall work and as from then, it loads the parameters (present in the knowledge base) characteristics from the database. These characteristics include the format of data (raster map, class, constant value), the version (update time) and the set of classes describing all the possible values of each parameter (which will appear as different colours of the map on display).

Starting from the map of fuel models, relative humidity and air temperature several output maps predicting fire behaviour are derived. The fireline intensity map is selected and its pixels are interpreted in terms of fire severity

Figure 3 shows how the fire severity is computed, by a combination of equations and expert rules contained in the knowledge base.

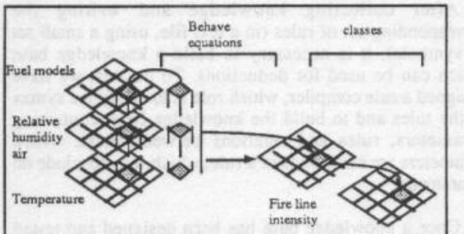

Figure 3: Danger Index Maping : the Fire Severity

Conclusion

The integration of danger rating methods in a decision support system gives to managers a powerful tool for decision making. Two important features must be achieved: update these data by monitoring the situation and allow experts to create and update their own methods.

The FMIS system (Wybo et Meunier 93) has been designed to reach these goals by associating autonomous processing and knowledge based assessment of data.

Automatic acquisition of data is essential to danger assessment in the sense that managers must be aware of the situation and its evolution but, to be fully efficient, this automation has been extended to the management of data processing and danger indexes updating.

The four indexes presented in this paper give to the managers a precise idea of the danger level in the different aspects of wildfires. This information can be used for prevention tasks, for instance to start patrolling in most sensitive areas; it can also be used to help decision making when a fire event occur.

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SEVERE WEATHER

BRMS: MONITORING BASIN RAINFALL AND POTENTIAL FLOODING

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Abstract

The Basin Rainfall Monitoring System (BRMS) is a new development of the Forecast Systems Laboratory's Dissemination Project. Since 1992 the Dissemination Project has been conducting experiments to determine the use of advanced meteorological information by local government operations. Local emergency preparedness agencies (involving emergency preparedness, sheriff and police departments) can gain great benefit from appropriate information about weather hazards. The Dissemination Project, a pilot project, employs a workstation especially designed to focus on four weather hazards of particular importance to emergency preparedness: flash floods, fire danger, severe weather and disruptive winter storms. The BRMS complements the workstation in assisting emergency managers in evaluating flash flood situations. The system uses high-resolution weather datasets produced by analysis and prediction models, and the WSR-88D radar, which provides mesoscale detail about rainfall distribution that is not available from gauge networks. When in the surveillance mode, the BRMS alerts users if flood danger is high. Users are then able to request more detailed products on the workstation, and the system computes assertions, weather characteristics related to spatial (regions) and temporal (periods) objects such as river basins and storm evolution. Emergency managers can use the meteorological displays to analyze flooding conditions over several basins, which enables them to better forewarn the public of flash flood potential.

1. Introduction

Flash flooding usually occurs in narrow canyons or urban areas shortly after or during heavy rains, especially during summer convective storms [White 1975], and can cause deaths, severe property damage, and traffic disorders. To minimize loss of life and economic damage, emergency managers must be able to predict the flash flood event and take certain actions, some of which are expensive and may inconvenience many people, such as evacuation and traffic closure. The decisions they make are based on various sources of information: weather data and state of the community: holiday celebration, rush hour traffic, or rest time. Of course, physical factors such as soil moisture, surface characteristics and reservoir water levels are very important to the type of decisions made. The more accurate and timely the information, the better their decisions. Furthermore, the false alarm rate, which can cause people to not respond to a real emergency, will be lower. In addition to the accuracy of the information used by emergency managers, another factor that influences the quality of the decisions is the stress level of the decision-maker. Emergency managers work under pressure mostly because of severe time constraints. For example, the period between the initial rainfall and the consequent flooding is often less than an hour, a very short period to monitor the amount of rain fallen over the river basin and decide on appropriate actions.

The characteristics of flash flooding led us to design a system that supports emergency managers in evaluating flash flood situations using high-quality weather data. The BRMS uses gridded data fields from an analysis and prediction system, and presents the data at different levels, from summary information to a very detailed level, in various modes: images, maps, graphs, text, and tables. A summary product is provided as the first level of information; this allows users to quickly make a preliminary judgment of the situation, and, if warranted, they can further explore the situation by requesting more detailed products with a simple click of the mouse. The optional modes of presentation allow the system to prepare efficient displays that correspond to the type of information being presented (spatially or temporally distributed, summary or detailed).

BRMS is one of the experimental decision support systems developed within the Dissemination Project [Small 1993]. This project is intended to study the utility of advanced weather data sets to various users, such as emergency and traffic managers. NOAA and local emergency preparedness staff realize that the official method of disseminating local weather data through text bulletins can be significantly improved with graphics and other means of expression. The methodology adopted in the Dissemination Project is to develop experimental weather decision support systems, install these systems at various evaluation sites, get feedback from real users, and repeat the cycle again.

To illustrate the need to develop systems such as BRMS, we describe one of the most devastating flash floods in the nation, the Big Thompson Canyon flash flood, as well as the lessons we learned from it. Then the data sources used in BRMS are discussed, and we argue why the use of hydrological models is currently inappropriate. Next we introduce the features of FSL's approach to system design, the system architecture, and the user interface. Some implementation issues are addressed before the concluding remarks.

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2. The Big Thompson Canyon Flash Flood

One of the most severe cases of flash flooding occurred on 31 July 1976 in the Big Thompson Canyon, Colorado [Simons 1978]. During that evening, an intense thunderstorm stalled over a small portion of the canyon dropping over 10 inches of rain in a 3-hour period. Because the topography of the canyon is steep and mountainous, the rainfall quickly concentrated in the stream and formed a wall of water that swept away everything in its path. Trees, sediment, boulders, and even houses were swept downstream. The final toll of this flash flood event was staggering: 139 people dead, 4 missing, and property damage exceeding $41 million. The reason for the huge toll on life is twofold. First, the flood struck an area that was totally unprepared for such an event. Second, there was little effective warning with significant lead time for the 4000 people who were celebrating Colorado's Centennial Celebration in the canyon, and the many residents of the developments that had encroached onto the floodplain. The huge toll on property was mainly because of lax or nonexistent zoning restrictions for both commercial and residential development of flood hazard areas.

Boulder County, has a similar, if not a worse, scenario with Boulder Creek. Boulder Creek has a steep mountain topography and a short concentration time similar to the Big Thompson canyon, but is worse because it runs through the city of Boulder. More important, there is tremendous development and a high population density along the creek and its floodplain.

The after-effect of the Big Thompson flood reminded people of the substantial flood hazards in mountain canyons. Cooperation between the various public safety, flood control and emergency management agencies was excellent. The Urban Drainage and Flood Control District (UDFCD), Boulder County, and the City of Boulder worked together to develop and implement a flood detection and warning system to reduce the loss of life if a similar flood should occur in Boulder County. To better detect rainfall, rain and stream gauges were installed on the watershed and streams. Hydrological consultants and the Corps of Engineers analyzed the creeks and streams, and their analyses were used to formulate a flood detection and warning system. The hydrological analysis of the creeks showed that flood flows can develop in the canyon within 1 to 2 hours of peak rainfall, and the time for it to travel down to populated areas is considerably less, typically between 30 and 50 minutes. Thus, in a worse case scenario, flooding can occur in Boulder within three hours of the beginning of rainfall. The warning process requires a much longer lead time than the period from flood detection to flood arrival. It necessitated the detection system to be activated during storm development and warnings issued 30 to 50 minutes before upstream flooding is detected to provide adequate time for the public to respond. The warning process would use alert radios, sirens, public address systems on emergency vehicles, and the broadcast media where the emergency manager can tap into the network television stations and send out alerts to the public.

3. Data sources

Emergency managers use weather information as one of their key data sources for decision-making. Currently, accurate and comprehensive datasets about certain weather variables such as temperature, relative humidity, precipitation type and amount, and wind velocity are produced by different analysis and prediction models. Two models are being developed at FSL to analyze and predict the weather at different spatial and temporal scales: the Mesoscale Analysis and Prediction System (MAPS) [Benjamin et al. 1991] and the Local Analysis and Prediction System (LAPS) [McGinley et al. 1991]. They both produce gridded datasets from various sources: radar, automatic surface and upper-air measurement, and satellites. The grids have different spatial and temporal resolutions and domains: the MAPS grid has a 60 km spatial and 3-hour temporal resolution that covers the United States, and LAPS grids have a 10 km spatial and 1-hour temporal resolution that cover approximately an area as large as Colorado.

Another source of information is the newly installed WSR-88D (previously NEXRAD) radars that provide both reflectivity and velocity [Kelsch 1992]. From these radars, information of reflectivity and its derived products such as rainfall accumulation can be obtained with a resolution of 2 km every 6 minutes [Smith and Lipschutz 1990]. A second type of LAPS grids is planning to use this high spatial and temporal resolution in the future.

For the type of flash flooding analyzed here, high resolution precipitation amount is the most important weather variable. State variables such as stream levels that can be obtained from stream gauges and river basin soil moisture are other important variables. Although the estimation of rain rates from radar reflectivity is not very accurate, it is sufficient to start experiments, and there is the strong expectation that it will improve in the near future [Rasmussen and Smith 1989]. This rain-rate dataset with a spatial resolution of 2 km updated every 6 minutes can be viewed as having automatic raingauges at every 2 km which would be prohibitively expensive to install and maintain physically. However, currently, a limited number of raingauges are located sparsely over the river basin. Basin-wide rain averages are obtained using the Theissen polygon method, but it has a drawback of being unable to detect the small-scale convective storms that are located in between the raingauges. This can lead the decision-maker to make the erroneous and dangerous judgment of "no flood danger."

Emergency managers can benefit from other information such as the following basin characteristics: time to peak, shape, size, topography, soil type, and vegetation. Some of these parameters may not be used during an actual flooding event, but they can be used by decision-makers to familiarize themselves with the river basin under their responsibility. Such data can be produced by rainfall-runoff hydrological models such as the Precipitation-Runoff Modeling System (PRMS) and the Hydrologic Engineering Center's HEC-1 flood hydrograph model [Bedient and Huber 1988]. Although these models, provide the potential for very accurate predictions of flood danger for river basins, using the radar derived rain rates and the rain input, they have two fundamental drawbacks: they need parameters that are hard to obtain, and the model runs take too long to monitor many basins simultaneously. Therefore, we took another approach in designing a system that is simpler and could prove to be helpful to the decision-maker.

4. The FSL approach - a new system design

After considering the problems of emergency managers in a city and county office, we have designed a system that supports the decision-making process. Our design comprises the following features:

- A data source from the LAPS model and the nearest radar located in Denver, which provides rain-rate data at 2 km resolution.
- A Geographical Information System (GIS), called ARC/INFO, provides data for other variables such as soil type, basin area, and vegetation. Other basin characteristics such as time to peak were obtained from basin analyses by the UDFCD and the Corps of Engineers. Soil type and vegetation are used in a separate model that computes the field soil moisture, which in turn has direct effect on the level of flooding.
- The information is presented on multimodal displays using images, maps, tables, text, and charts. Each mode presenting different aspects of the information that are consistent with one another and build on each other.
- Original data are presented as well as summarized information.
- Some derived variables such as basin and subbasin flood danger mode are computed, in addition to pure weather variables.
- Simple action rules, obtained from the County Warning Plans associated with the corresponding flood danger mode, are suggested to make the presentation more familiar to users, and to remind them of certain important actions they must undertake.
- Hypermedia access to the information is provided, starting from a summary surveillance product and going into more detailed ones.

5. System Architecture

Since BRMS is supposed to work in a distributed environment (Section 8), we adopted a highly modular structure, each module fulfilling a separate, well-defined task and communicating with the other modules via standard types of messages. There are six processes that run in the system:

- **From grids to bitmap images**. Converts raw gridded data into Windows bitmaps. A lookup table (LUT) encodes each weather parameter value into a color. For example, the temperature parameter has a LUT that goes from light magenta for the lowest values to red for the highest values. Each grid point value is converted to a color using the LUT, and then a colored box representing the temperature of the grid point is drawn on the screen.
- **From grids to assertions**. Converts raw gridded data into assertions providing immediate answers to questions the user is likely to pose in a situation of flash flooding. The assertions are organized into coherent chunks of information so that the user can better perceive them and create a mental representation of the situation. As explained in greater detail in Section 6, the assertions are weather or other characteristics related to spatial and temporal objects known to the user. Territory and time models define the regions and periods used in assertions. The characteristics are values of certain variables organized in a parameter model.
- **From assertions to maps**. Presents a set of assertions about different regions into a map, in which each assertion is represented by an icon. To do this we designated a spot for each region where the icon should be placed. The color and the shape of the icon depend on the assertion parameter and value. Maps are used for presenting the flood danger for the different basins and subbasins (cf. Section 7).
- **From assertions to text**. Text is used when assertions represent heterogeneous information such as extreme and mean values of rain rate, non-weather characteristics such as time to peak, action rules (e.g., "Evacuate people from buildings along the creek.") and trends. The text generated by BRMS conforms with a template predefined by the designers of the system. This template specifies constant phrases with slots for assertion values and action rules.
- **From assertions to charts**. A chart is used for presenting the dependency of one variable from another, for example, the evolution of the rain rate over a particular region.
- **From assertions to tables**. Presents the same time series that is displayed as a bar chart above as a table. The table in BRMS contains the rain rates every 18 minutes of a 3-hour and 36-minute period.

The process "from grids to assertions" is carried out by the assertional subsystem; its functions are described in the next section. All other processes are carried out by a presentation subsystem, which also accepts the user's commands that are given by selecting from menus or by clicking on visual objects that are already displayed.

6. Assertion generation

Assertions are weather characteristics related to spatial and temporal objects. The spatial objects, called *regions*, are of particular importance and they are defined in a territory model. The territory model contains the following information for a region: *name* (e.g. Boulder), *type* (e.g., county, city, basin), *carrier* (the set of grid points that belong to the region), and the *superregion* link (a region *A* is a superregion of another region *B*, if *A* contains *B*). The temporal objects, called *periods*, are predefined and hard-coded in the current version of the system. The weather characteristics are computed by applying certain methods to the gridded data that relate to the assertion region and period. Some broadly used methods are mean value, accumulation, maximum value, minimum value, and predominant (mode) category. The weather variable and the method, taken together, represent the *parameter* of the assertion. As a result of the computation of a parameter for a region and period, a *value* is assigned to the assertion. A comprehensive description of the current state of the assertional system featuring complete territory, time, and parameter models can be found in [Kerpedjiev 1993].

The BRMS uses a territory model with four basins in the Denver metropolitan area. Each basin consists of several subbasins, which are subregions in the terminology of the territory model. The basins and some subbasins are shown in Figures 1 and 2, respectively. Assertions are generated for a period of 3 hours and 36 minutes, which is divided into twelve 18-minute subperiods. Two gridded variables at spatial resolution of 2 km are used as input to the assertional subsystem: rain rate and soil moisture. The following parameters are used:

- **Rain accumulation.** Provides information about the total amount of rain received by a region over a given period.
- **Predominant category of soil moisture.** Indicates the wetness of the soil. The wetter the soil, the smaller the proportion of rain absorbing into the soil and the greater the proportion of water contributing to the flood. Four categories of soil moisture are used: dry, moderately dry, moderately wet, and wet.
- **Storm frequency/recurrence interval.** Indicates the flood danger as a storm recurrence interval. It is obtained using the Frequency/Depth/Duration analysis for 2-hour convective storms by the UDFCD. A 100-year storm, for example, means that this size storm happens on average once every 100 years. Thus this storm has a 0.01 probability of occurring in any single year. A 100-year storm is an extreme storm event and probably requires evacuation.
- **Rain index.** Indicates the flood danger for a region by using the maximum 1-hour rain accumulation and the UDFCD Urban Flash Flood Guidance for short duration storms (less than 1 hour). The UDFCD obtained these values by analyzing the mountain streams in the Front Range area.

Assertions for several time-independent parameters are precomputed for all regions and stored with the territory model. Examples of such parameters are basin area and time to peak.

Individual assertions, organized into a time series, or assertions representing a regional description are submitted to the presentation module which generates the corresponding display: map, text, chart, or table.

7. User Interface

The BRMS can be in one of four modes: general surveillance, basin survey, subbasin, and color image display of weather data. General surveillance information is given as a map of the four basins (Figure 1). A frame of a certain color surrounds each basin. The color of the frame corresponds to the highest rain index detected in that basin. Figure 1 shows that the rain index is 2 (high) in three of the basins and it is 3 (very high) in the fourth basin. This display allows users to immediately detect if there is any flood danger in their area of responsibility.

By clicking anywhere within the frame surrounding a basin, the user gets into basin survey mode, which provides a detailed map representing the flood danger modes of all subbasins within that basin. The rain index for a subbasin is given as a box over the subbasin (Figure 2). The color of a box corresponds to the flood danger for the corresponding subbasin. Figure 2 shows that the subbasin with rain index 3 is closer to the mouth of the creek, which means that the flooding may occur sooner than the average time for this basin.

Clicking on the box of a subbasin gets the system into subbasin mode giving more detailed information about this particular subbasin in the form of text, chart, and table (the right hand part of Figure 2). The chart on this display is particularly informative because it shows when the heaviest rain occurred. The exact values of the rain accumulation can be found in the table next to the chart. The text on the top right corner provides diverse information about the current situation.

The user can also select a particular variable from a menu whereby the field of that variable is presented as an image (e.g., the rain rate field is shown in Figure 3). This high-resolution display allows users to monitor where and when the heavy rain occurred and to adjust their perception of the situation. Other fields such as radar reflectivity are also accessible from the menu and presented to the user as an image.

8. Implementation Issues

The current Dissemination Workstation consists of three parts: a central server which acts as a file server, the FSL VAX computer cluster which stores all FSL meteorological products, and the Visualization IBM Personal Computer (PC) which displays the meteorological and environmental information to the Emergency Manager. The Visualization PC is a generic, off-the-shelf DELL 486 IBM compatible PC; it uses MS-DOS 5.0 and Microsoft Windows Version 3.1 as its operating system. The PC is connected to the central server on the FSL VAX cluster via a 56 kbaud modem-router combination and uses the Digital Equipment Corp. (DEC) Pathworks communication utility.

The assertional system was written in FORTRAN, and the presentation system was written in Microsoft Visual Basic.

Currently the Dissemination Project deploys two PCs outside FSL. One is in use at the Boulder County Emergency Services Office and the other is located at the Denver Weather Service Forecast Office. The initial response from the officers using our system is positive.

9. Concluding Remarks

This paper describes BRMS, a system designed to help emergency managers create graphical interpretations of flash flood situations to help them react appropriately so that disasters like the Big Thompson flash flood can be mitigated. The system, which supports the mission of the Dissemination Project, provides four types of displays with different spatial scope and level of detail. In surveillance mode, it detects and shows the existence of any flooding conditions over several basins. In basin survey mode, it indicates in categorical terms the amount of rainfall over the subregions of a basin, allowing the user to infer how this rain will contribute to a possible flash flood. In subbasin mode, BRMS provides details about the temporal pattern of the rain, as well as various characteristics of both the basin and the rainfall. Additionally, BRMS provides for action rules, actions to be taken in response to certain events, which are based on the county flood warning plans. In rain rate mode, the system allows the user to view the spatial pattern of the rain with very high resolution. The images are directly generated from gridded data, whereas the other types of displays are created from assertions, which in turn are produced from gridded datasets.

We expect more feedback from the current users that would allow us to make a better judgment of the utility of BRMS. Currently, we are developing a technology for adapting BRMS to other regions, as well as expanding its scope to other types of weather hazards. As FSL is moving toward the world of Open Systems, we need to adjust our architecture to the new computing environment as well. Another area of research that is going on in the Dissemination Project and might influence BRMS is the development of a new assertional and presentation system supporting a wide variety of descriptions and modes of presentation.

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Figures

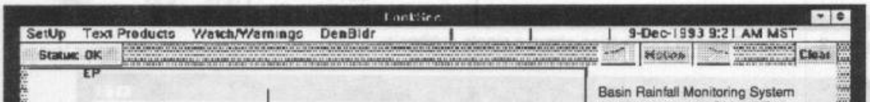

Figure 1. Basin Rainfall Monitoring System (BRMS) in surveillance mode.

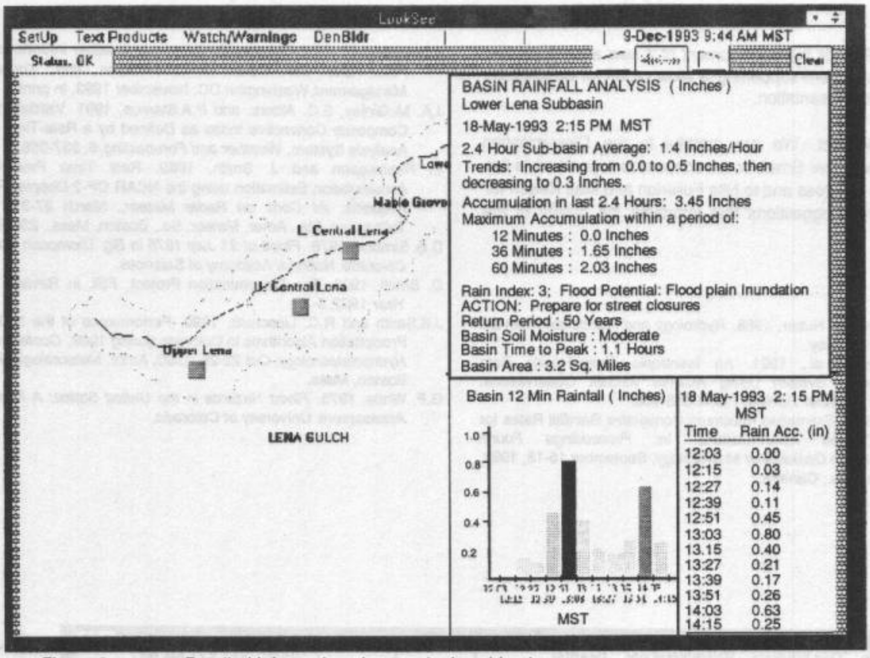

Figure 2. Detailed information about a single subbasin

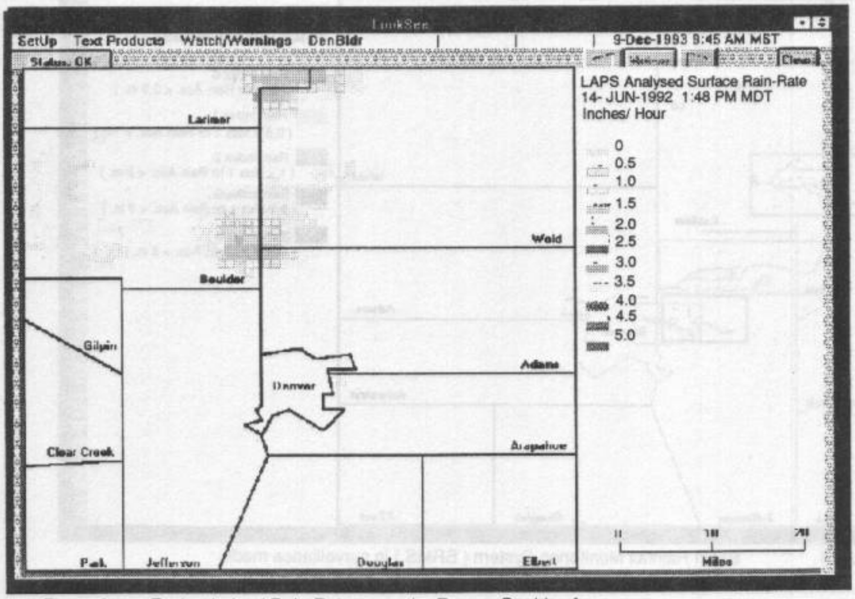

Figure 3. Radar derived Rain-Rates over the Denver-Boulder Area.

CREEPING CRISES: DEVELOPING THE TECHNOLOGY OF COASTAL ENVIRONMENTAL MANAGEMENT

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ABSTRACT

Expert systems and crisis management constitute both individually and collectively new agendas within the realm of public management, policy research and development.

Creeping crises, as protracted disaster episodes which can, in a rapid succession of events, reach peak moments where danger materializes and transforms into acute crises, are not well understood in planning or decision-making terms. Not only are creeping, as against immediate, crises unconventional, because they lack the test of 'unness' (Hewitt, 1983: 10), they also represent a set of cases which prove taxing and intractable to many operating agencies. 'Denial', 'wait-and-see' and 'band-aiding' are common responses to creeping crises by government agencies and interest group supporters whereby ultimate responsibilites are often difficult to define, let alone to be held accountable.

Environmental crises deserve sophisticated policy and planning analysis for what they are: serious economic, political and, often, international issues. This paper seeks to develop GIS capabilites with more complex coupling of the issues of territory, task, technology and, especially, *time* within environmentally-specific protracted crisis contexts. Referring to Australian coastal ecologies, various planning phases, or paths, identify specific environmental factors and more complex institutional, technological and spatial relationships required for enhanced professional planning capabilities at local, regional and, even, national levels.

The 'time paradox' inherent in creeping crises demands an additional planning capability; one that might be called a capacity to understand and incorporate a *time budget* into GIS-based planning systems. Professional environmentalists and planners can move towards designing futuristic, simulation-capable GIS's crucial to the 'think locally, act globally' dictum. The paper identifies some design agendas necessary in enhancing such professional capabilities and creeping crisis planning effectiveness.

INTRODUCTION

At the 1993 conference of the Computer Simulation Society, several papers were presented to discuss the growing use of geographic information systems (GISs) for emergency/disaster management (Newkirk, 1993; Sullivan, 1993). For the most part, such work was studied in the temporal context of 'immediate crises'; that is, hurricanes, earthquakes and floods. This paper will not focus its attention on these well-known topics; rather, it will be less conventional and shift the focus of study toward 'creeping crises' (Rosenthal, 't Hart and Charles, 1989: 27-28). Such crises are unconventional because they lack the tests of 'un-ness' (Hewitt, 1983: 10): in practice, they are spatially specific (a wetlands ecology), monitorable (by scientific control standards), plannable (using GISs), predictable (as best-worst case scenarios) and, even, computable (by using machine-based simulations). Despite all of these obvious managerial advantages, however, ecologies are barely improving in nature - for example: wetlands deterioration; coastal deforestation; declining aqua-cultural protection; beach mining/erosion; river pollution (Jarman and Kouzmin, 1994b); and estuarine degradation. This list goes on. The US Vice-President (Gore, 1993: 42) is specific in this regard when he states: 'we see the destruction in slow motion'.

CREEPING CRISES: SOME INITIAL MODELLING

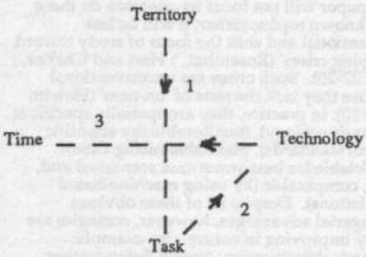
The persistence and geographic spreading of ecological/environmental degradation is ultimately more than a mere 'management' problem (Kouzmin and Jarman, 1989: 397-398; Rosenthal and Kouzmin, 1993: 8-10). Well-meaning coastal commissions, environmental protection agencies, local government planning agencies and others (even at international level) have not succeeded at 'stemming the tide' of such creeping crises. Therefore, *strategies* need to be reconsidered (Australian Resource Assessment Commission, 1993).

Use will be made of a relatively old, but unconventional, systems model developed by Miller (1959) which inter-relates three key variables strategically: Technology, Territory and Time. While respecting its original use, we will add the variable of Task. This addition allows one to manipulate these four independent variables in sequence so that for any environmental creeping crisis, as a time-dependent phenomenon, the following pattern of planning activity can be studied:

Path 1: Territory to Task
Path 2: Territory to Task to Technology
Path 3: Territory to Task to Technology to Time

In this schema (see Figure 1), more complex institutional (strategy/operations) relationships become necessary; spatial relationships are more focussed; technological options more open, while time-frames become more negotiable given the broad range of possibilities defined in Paths 1, 2 and 3. This situation may be expressed diagrammatically as shown:

Figure 1



Path 1: Territory to Task. In the case of Australia's coastal ecologies (Territory) three distinct zones can be identified:

Far North:	truly tropical, monsoonal hurricanes (zone 1)
Central:	Mediterranean climate, storm surges (zone 2)
Southern:	more temperate, severe storms, major river flooding (zone 3)

Our example of the localized 'creeping crisis' area will be the City of Wollongong in New South Wales (NSW), with a population of 180,000 people; generally a beautiful coastal site dominated by its steel industry. To highlight the issue of creeping crises, the GIS now being finalized by the City Engineering Department has been designed to perform the following tasks:

1. Procure state-level geographic maps in digitized form (State Land Information Council - SLIC) and then cleanup; that is, reduce the error rate in the data. Some of these error rates can be significant (greater than 20 per cent).
2. Finalize the database (digital) map as vector-related data in the mapping system (Hewlett, Packard/Genemap GIS).
3. Cross-tabulate this 'map' with the financial database stored in a different computer and make the two systems inter-operative.
4. Add engineering and planning attribute data layers to this GIS.

Path 2: Territory to Task to Technology. The second path, Territory-Task-Technology, constitutes logically a more complex configuration of the putative three-path schema. The new possibilities emerging from the next (and imminent) generations of aerial photogrammetry and satellites is mind-boggling (Jarman, 1993).

At an applications only level of analysis (demand-side), the relationship of a new generation of sensors (supply-side) to crisis planning generally is operation-level with regard to both monitoring necessity and capability. A brief list of enhanced applications capability will suffice:

- Weather forecasting (El-Nino Southern Oscillation);
- severe storm radar (NEXRAD);
- 'see-through' cloud radar (synthetic aperture radar, for example, Canada's RADARSAR, ESA's ERS-2 and Japan's J(ERS)-2);
- multi-band land monitoring (TM LANDSAT 7);
- land photography to resolution of 1-10 metres (US and Russian reconnaissance satellites);
- aerial digital othophotographic (various scales and GPS-enhanced resolution);
- local aerial photography using digital techniques; and
- NASA/Freedom Earth Observation System (EDS-EOSDIS).

The relevance of this new technology to 1997 (only three years) to the development to creeping crisis analysis may not immediately be obvious. A few guidelines may be presented briefly as follows:

- Base-map raster-to-raster digitizing of flood-plain/wetlands area;
- GIS layering (additional attributes) raster-to-vector for flood-plain scenarios (20-50-100 years); storm-water run-off (rural versus suburban); flora-fauna ecology;

toxic sediments; and hazards management analysis;
- traffic management planning (both normal and evacuation scenarios); and
- beach-area change (onshore/foreshore analysis; storm surge scenarios; storm-water pollution effects; flood chemicals spillage; estuarine ecological change; and ocean oil-spill scenarios).

To our knowledge, no Australian GIS is capable of providing such basic data on demand. But Path 2 of the schema requires such a comprehensive data-set and, certainly, the vector-based scenarios required for efficient and effective long-term creeping crisis strategic planning. In this sense, demand far outstrips supply and will continue to do so even when the terrestrial/space technological capabilities come 'on-stream' later in the decade.

Even worse, if viewed from the strategic perspective of an individual local authority (LA), even in Wollongong City with a budget in excess of $A150 million, the cost-effectiveness of such enhanced systems remains problematic. Some reasons are:

- Inexperience of general staff using the existing GIS (training);
- cost of additional GIS layers which are non-revenue generating (net revenue ratio low); and
- inexperience of professional staff with space technology applications to date (future applications knowledge).

In adding the new layers, engineers might want to specify the mapping coordinates of such facilities as road-centre lines, kerb and gutter locations, man-hole centres and water/sewerage piping layouts. This data must be geographically accurate relative to cadastral points (ground truthing) and today is verified using either conventional surveying techniques or differential Global Positioning Systems (GPS).

If regarded as a 'southern zone' city, the basic GIS described above would need to be enhanced for ecological monitoring purposes whereby five immediate layers would need to be added:

- Flood-plain mapping (20-50-100 years);
- toxic materials sedimentation;
- storm-water run-off patterns;
- flora and fauna wetlands data; and
- new suburban (West Dapto) evacuation schema.

Wollongong City monitors some of this necessary data which is now used as part of the Council's GIS.

The Territory-Task-Technology relationship constitutes an important analytical starting point for the development of an ecologically-relevant GIS. Normally, enhanced flood-plain GISs are a good way of defining operationally the relevance of creeping crises in such an area: toxic sedimentation; flora-fauna development; upstream suburban area flooding impacts and, finally, beach erosion. As for the impact of these new systems on the Pacific Ocean's aqua-culture potential, only guesses can be made at this stage of planning. Finally, in a topologically-structured GIS 'what if ... ' scenarios can be considered by strategic planners (for instance, rising ocean levels). Problems, however, remain with two prominent issues being:

- Uncertainty of mapping/GIS/GPS policy of both state and commonwealth governments concerning technical capability and cost-sharing arrangements; and
- intellectual property disputes both within LAs (staff innovations) and between LA and SLIC (royalties, licences and fees policy).

In summary, the Territory-Task-Technology combination represents a general mixture of institutional conservatism and technological opportunity (Rozzoli, 1992). The best data available at local levels may simply not be used by others outside the datum LA. The legal, financial and applications variables need to be considered as early as possible in the development of the creeping crisis-type GIS. This matter requires urgent consideration in all spheres of government.

Path 3: Territory to Task to Technology to Time. By adding the time dimension (Clark, 1985; Zerubavel, 1981; Benini, 1993) to the other three variables, a quite complex set of inter-relationships has been defined so far as creeping crises management (Jarman and Kouzmin, 1994b) is concerned. In theory, at least, it is possible to presume that, in this context, 'time is on our side'. Without wishing to appear unduly pessimistic, however, it is possible to state a worrying paradox based on the environmental management record of governments during the past 20 years.

The paradox implicit in Vice-President Gore's (1993) statement above may be written as a hypothetical statement: 'The more time governments have, so the more time they seem to need' to solve such non-routine, and presumably non-urgent, types of crises.

In Australia, the Territory-Task-Technology-Time situation is demonstrably complex in many ways: the least complex of which ironically is 'technological'. More abstractly, the concept of a *time-budget* stated as a supply/demand equation is curiously absent from much of contemporary governmental policy-making. Therefore, this type of time-budget needs further analytical scrutiny and development. Briefly stated, the temporal situation is as follows:

Demand-Side

- Governmental spheres which do have the input resources (especially at federal level) do not always possess the legal powers and/or political will to recognize that 'a problem even exists' ('t Hart, Rosenthal and Kouzmin, 1993; Jarman and Kouzmin, 1993: 19).
- When seeking to gain such governmental 'attention', non-governmental groups seek to dramatically use 'media-grabs' so as to incite 'crisis-states' of affairs (Rosenthal, 't Hart and Kouzmin, 1991; 't Hart, 1993). The 'cry wolf' syndrome can ultimately effect the intensity of such messages to government and the general public.
- In the past, conventional science policy advice concerning such imminent 'crises' does not seem to have been able to instil a sense of urgency in most key policy groups within government (Rosenthal and 't Hart, 1991; Jarman and Kouzmin, 1994a).
- Technologists seem to have fared even worse in the 'centre of power'. As 'non-scientists', they seem to lack causal knowledge credibility with government.
- Community-level advocates, whilst articulate locally, find it difficult to develop even a state-wide support base, let alone one of national significance.
- Governmental science bureaucrats are not always free to speak - either by tacit disapproval or censorship, or to publish findings which may embarrass governments or private industry.
- LAs, who know their local needs best, are not well-resourced enough to develop their own basic GISs quickly enough for routine uses, let alone more 'exotic' applications (Wolensky and Wolensky, 1990).

Supply-Side

- LAs and other governmental mapping/environmental protection agencies suffer from an already chronic 'deluge of data'. The advent of digital orthophoto and, even worse, synthetic aperture radar (SAR), will only exacerbate this data overload.
- Until more sophisticated 'data comprehension' software systems become operational, this data glut may well impede 'information-level enhancement' whereby better scenario-generation, decision support and expert systems cannot be afforded because of data handling costs.
- Software operating systems inter-operability, while problematic at local level (say, for water-shed modelling coordination), is likely to be even less useable with regard to the new generation of federal environmental data-bases.
- Even where such federal-local inter-operability is technically possible, federal data is likely to be, in mapping terms, of inappropriate scale and resolution for effective use as a data source at local level.
- With regard to space technology, the (Australian) federal sphere of government is almost wholly dependent on overseas data sources (NASA, NOAA, ESA, JSA). As such sources seek to commercialize because of governmental 'user pays' requirements, so vital types of data (for example, SAR) may not be 'affordable'.
- Many LAs will need to be encouraged by the provision of governmental subsidies to add ecological/environmental data layers and information system enhancements to their parochially-designed databases.
- LAs, even of the innovative variety, will continue to need expert support so as to develop, quickly and effectively, expert system prototyping capability. This is a matter of genuine urgency (Hadden, 1989).

CONCLUSIONS

Since 1989, a renewed governmental effort concerning environmental issues has forced itself onto the global agenda. The UN conference in Rio, in July 1992, represented the largest meeting ever of heads of state and G 7 governments (Adede, 1992). At that historic meeting, the world was urged to 'think locally, act globally'. More recently, the international business community has pointed to the eventual development of a goods and services industry of $US200-300 billion by the Year 2000 (Crawford, 1991).

This short paper has concentrated on this exhortation to 'think locally'. It has sought to provide a first approximation schema to help professional environmentalists and others to do just that. A well-designed, futuristic, simulation-capable GIS is an important step toward this goal. The schema, applied to Australia's eastern seaboard, has been used to derive three important issues for further local-area policy makers to consider.

Path 1: Territory to Task. Determine, by mutual agreement, at an inter-government level of discussion, the *datum standards* of environmental control relevant to the territorial issues of local importance. The levels of nutrients entering the pristine ocean waters of the coral Great Barrier Reef (Zone 1) *must be less* than for southern waters (zone 3).

Path 2: Territory to Task to Technology. Begin immediately to integrate and incorporate into local-level GISs both terrestrial- and space-related technological capabilities. Simply entering the digitized GIS data itself can be a monumental and expensive task (probably 75 per cent of the total operating system). Space-sourced data requirements will be even more demanding. But, as such data becomes more appropriate to the needs of local-level agencies (scale and resolution enhancement), so LAs need to be experienced with its use. For most professionals, learning to use such novel technology can constitute a decided technical challenge (Kouzmin and Jarman, 1990; Jarman and Kouzmin, 1991).

Path 3: Territory to Task to Technology to Time. One seeming paradox has been asserted regarding common official responses to creeping crises: 'The more time you have, the more time you seem to need to solve such problems'. Perhaps it is time for local and regional agencies to forget (for the moment) their day-to-day budget issues and begin to prepare *time budgets*, perhaps using basic Critical Path Method (CPM) techniques. To perform this task professionally, however, the basic agreements required in Path 1 must be substantially achieved. Moreover, Path 2 also needs to be known so that the critical 'learning curve' aspects of the developing technologies can be tested by local-level prototypes for their cost-effectiveness.

Finally, all three creeping crisis paths need to be considered now as a matter of local/regional urgency. As this paper has suggested, overcoming local/national/global inertia is no simple or easy task. On the other hand, local activists are now increasingly articulate about their needs, state agencies are becoming more responsive to local planning systems (which will differ from place-to-place), most of the technology is already operational and, significantly, applications cost-benefit relevance is better understood. Importantly, some business people are interested in an emerging market place while globally the United Nations will play a continuing role in bringing some of these issues to international attention - an achievement in itself. Conceptually, this paper does not seek to address all of these issues - it is one modest attempt only to specify one way that 'think(ing) locally' might be considered as a strategic challenge but tactical opportunity.

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A SYSTEMS APPROACH TO THE MANAGEMENT OF CYCLONE DISASTERS IN INDIA

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Abstract

This paper represents the Cyclone disaster situation in the framework of a systems module. A model flow diagram for simulating the decision making in cyclone disaster management is depicted. The disaster physical planning measures, as taken in the past, are outlined.

1. Introduction

The disastrous features of a cyclone are associated with

i Storm surges or tidal waves.

ii Heavy rainfall

iii High velocity winds

The sudden rise of the sea level along a coastal belt is caused by the sudden pressure fall or depression in the atmosphere and this sea wave is called the storm surge or tidal wave. The destructive potential of cyclonic storms is maximum along the coastal areas and reduces as we go further in-land.

Tamilnadu, a state of India, is flanked by the Bay of Bengal and the Arabian Sea, is highly vulnerable and frequently subjected to overwhelming devastations by natural calamities due to cyclonic storms and flooding in its coastal districts. Owing to these disasters, loss of human lives, cattle, damages to huts, public buildings, crops, lands, irrigation sources, roads etc. occur almost every year. Pre disaster advance planning, community preparedness for disaster management and emergency relief organisation have been integrated and woven into the network of State Development policy in the form of a "State Anti-Disaster Plan".

Disaster Management

The objective of disaster management is to promote the prevention, control and prediction of disasters. Three important aspects of the systems are:

i. Disasters constitute a major development problem for most disaster-prone countries.

ii. Most disasters can be prevented; and

iii. The most basic preventive measures are also the least expensive.

Disaster management consists of preparedness and response at primary (the target areas, the community) and secondary (institutions and agencies, usually urban based) levels. These are further classified into activities such as forecasting, warning, evacuation, rescue, relief and rehabilitation/reconstruction. The effectiveness of disaster management would depend on:

i Physical infrastructures

ii Organisation structures

iii Culture/knowledge systems

iv Economic institutions and

v Training and research

The direct aims of disaster management (against disaster) are:

* Decreasing the level of potential risk
* Mitigating the consequences of disastrous action.
* Mitigating or preventing the development of a chain of disastrous events.
* Localising and limiting the scope of disasters.
* Facilitating rescue operations
* Facilitating organisations of general habitation during the first post-disaster period; and
* Facilitating and hastening rehabilitation and reconstruction activities.

The human being is a key figure in the disaster management system (DMS). Experience has shown that human beings are not altogether stable or predictable, and less so in times of crisis. The human being is not structured for invariant performance. The impending disaster creates an environment which contains insufficient, contradictory or redundant conditions under which man finds it difficult to function efficiently. Hence resort was made to a systems approach.

Elements of the System

Any systems analysis should first identify the elements of the system. The basic systems diagram of the Tamilnadu Antidisaster plan was identified as shown in figure 1. The elements are:

INPUT - defined as the energising or start-up component on which the system operates.

OUTPUT - defined as the result of an operation.

PROCESSOR - defined as that which makes possible the transformation of input into output.

SYSTEM PURCHASERS - those who set constraints upon objectives and hence the outputs.

FEEDBACK CONTROL - defined as the system function which compares output with a criterion.

The INPUTS of this system are:

1. Occurrence of the disaster, e.g. cyclone, floods, earthquake etc.- the resultant affected people, damage to property, etc.
2. Tools/Machinery which are required.
3. Financial Resources i.e. allocated budget.

The OUTPUTS are:

1. No. of lives saved - of people and livestock.
2. Value of property saved.
3. Minimised long-terms economic losses.

The SYSTEM PROCESSOR is the relief organisation consisting of:

1. relief personnel - trained manpower.
2. equipment to translate their efforts/commands
3. knowhow
4. departmental staff of the various govt. offices.

The SYSTEM PURCHASERS are:

1. Top management - relief commissioner's office
2. Public (for whom the organisation mainly exists)

The CONTROL which influences

both the Purchaser and the Processor consists of

1. Resource Limitations - Money, Equipment, Human
2. Time constraints
3. Uncertainty due to unpredictability of weather.

The FEEDBACK which has an impact on the control, can be identified as:

1. Public complaints
2. Death toll
3. Value of damage to property, crops, etc.
4. Future economic performance.

THE SYSTEM BOUNDARY

Every system exists in an environment separated by physical or conceptual boundaries. No system is completely autonomous and isolated from its environment. They are all inter-related in some manner or the other. For example, a university exists in a commercial, industrial and political environment and the activities of the campus are influenced not only by what is happening outside. However, the university cannot be bothered with all the activities of the outside world. Only those activities of the environment which interact with the university and affect the functioning of the system will be worth paying attention to. It is in this context that the concept of system boundary becomes important.

In the DMS, the concept of boundary restricts the scope of the relief problem to a size commensurate with the cost or time available for the relief operations and the amount of detail necessary, and including only those departments that are directly working for the relief of the people, to understand the process at a macro level. It is, of course, possible to view DMS in many ways and change the boundaries accordingly. The system designers' view should tend to relate the DMS to time state machinery as a whole, and not see it as an operating unit ful-filling a variety of minute needs and intricate details. A boundary for a system or sub-system is essentially to limit the problem of a manageable size - to assist in determining whether output fan be produced under the gives conditions of processor and input.

SUB-SYSTEMS OF THE DISASTER MANAGEMENT SYSTEM

Figure 2 gives the various sub-systems of the DMS and their line of interaction.

When a disaster, say a cyclone, strikes a particular area (coastal/low lying/or other vulnerable area) the damage manifests itself in the form of death of people and livestock, damage to property, damage to standing crops, submergence and salination of arable land, injury and infection of people and livestock leading to death or destructive epidemics, general deprivation for the population in the affected area, dislocation of services to the community at large, scarcity of foodgrains and other farm produce in the immediate future and in the long run such large scale economic losses that the country takes years to recover from.

A cyclone disaster can neither be avoided nor diverted from its chosen path. We can at best take-pre-cautionary measures to save the people, livestock minimise property loss and damage through proper zoning and land use laws; take prompt action to drain and desalinate submerged land; avoid overflowing of water-courses by opening the locks and gates at the appropriate time; dispense medical aid and food to the sick and hungery etc. All this calls for a "preparation plan"

The various sub-systems of the DMS are:

Top Management (1) - Relief commissioner's Office, Finance (2) - Finance Secretary (Revenue Ministry), Planning Cell (5) - Directorate of Town & Country planning, Medical Relief (4) - Directorate of Medical Services and Directorate of Public Health, Transport (6) - Transport Secretary, Maintenance (8) - Public Works, Highways, Irrigation, Fisheries Departments, Utilities (9) - State Electricity Board, State Water Supply & Sewerage Board, Telephones, District Management (3) - District Collectorate, Operations (11) - Field Officers of all the operating departments.

The sub-systems of the state machinery, that form part of the environment but that which interact with the DMS and affect the functioning of the system are as follows:

Publicity (7)
Forecasting Cell (10)
Civil Supplies (12)
State Government (14)
Central Government (13)

Upon receipt of the warning of the impending disaster from the FORECASTING CELL (10), the PUBLICITY (7) dissminates the information among the people in conjuction with TOP MGMT. (1), who coordinate and control the various material and information flow. The FINANCE (2) allocates the budget as required by the severity of the situation. THE PLANNING CELL (5) which consolidates all data plans for the initiation of appropriate action by the various departments. TRANSPORT (6) prepare itself to evacuate the people to shelters, move food-water supplies where required, provides mobility to the search/rescue teams, medical personnel etc. MEDICAL RELIEF gears itself, to the expected demands by stocking up medicines and other medical aid supplies. UTILITIES (9) takes such precautionary measures as shutting off power-water supply to prevent accidents and further avoidable damage; arranges for temporary telephone connections and other modes of communication to prevent a communication breakdown and to speed up co-ordinated action. MAINTENANCE (8) ensures smooth flow of materials from supply point to user point and also takes a number of precautionary measures. DISTRICT MANAGEMENT (3) is the 'men on the spot' catering with available resources to a dynamic situation. CIVIL SUPPLIES (12) Supplies foodgrains and other essential commodities.

The CENTRAL GOVERNMENT (13) and STATE GOVERNMENT (14) provide the required overview. OPERATIONS (11) is the actual transducer of the whole system which converts from mere concept to reality.

INFORMATION FOR THE DMS

Any system should function through a good information system; the decisions making will be effective only if the necessary information is available and accurate.

Data for the DMS should consist of such information as :

1. Accurate projected population figures - talukwise, villagewise.
2. Shelter location, capacity
3. Distance from shelter to village (for evacuation)

4. Vehicle capacity available (for evacuation)

5. Food requirements

6. Fooder requirements

7. Water requirements

8. Medical aid facilities required

9. Stocks available, foodgrains/medicines/fuel/...

The list would be very long. IN fact a very comprehensive information system is necessary in order to understand the dimensions of the task. Collecting, storing, retrieving and analysing information is vital for any system. Such information processing may be computerised (it is fact necessary in this situation where enormous quantity of data is involved).

Disaster Preparedness In Tamil Nadu

The Government of Tamilnadu for prepared a state anti-disaster plan containing comprehensive planning measures and various Regional, Rural, Urban and local policies. This includes:

i. Mapping and delineating the vulnerable areas and grouping this according to degree of vulnerability.

ii Providing disaster-resistant community shelters located at high levels.

iii Providing an effective warning system through simple warning devices.

iv Construction of core units in huts to safeguard the belongings of people during their absence after evacuation.

v Organising special training programmes for educating the people in the vulnerable areas and also to train district collectors and agencies responsible for anti-disaster programmes.

Studies and research have been undertaken for each of the above action plans.

SIMCLONE for training district collectors

The author designed, developed and administered a computer simulator titled SIMCLONE (Simulated Cyclone). This was in the nature of a mock game in which the players have to make decisions under uncertainty, with partial information under stress conditions. Figure 3 is the model flow diagram of SIMCLONE and figure 4 depicts the information flow between the players, Directing staff and the computer used for the game.

CONCLUSION

In conclusion, all these exercises so far undertaken viz. identification of vulnerable areas and land use planning, setting up of cyclone shelters installation of warning devices, development of core units, Simclone exercise will all be pursued with vigour, modified and improved based on performance and acceptability characteristics, continued with more and more new developments founded on Research and investigations - all are done of course with the knowledge that though we cannot prevent disasters, atleast we can mitigate the evils, hardships and damages caused by them. We go ahead with our task with the firm belief that any amount of time, energy and finance spent on these progrmmes are bound to lead the country to economic prosperity.

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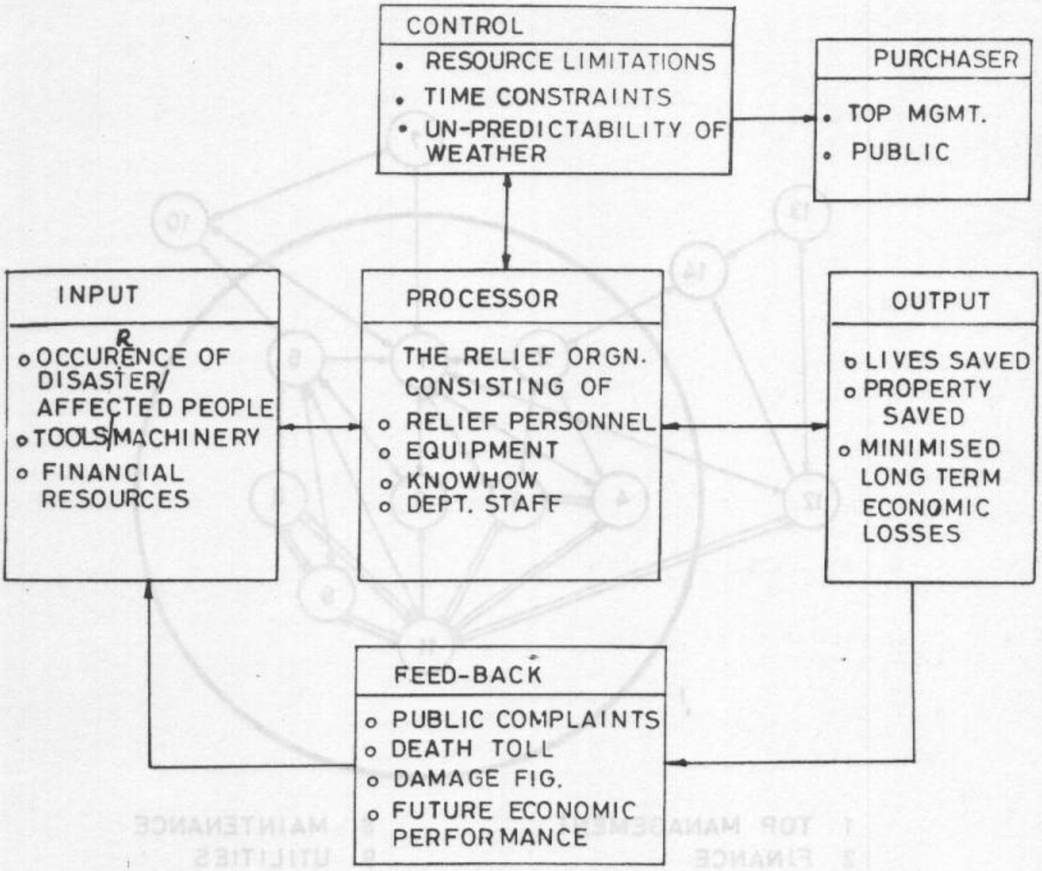
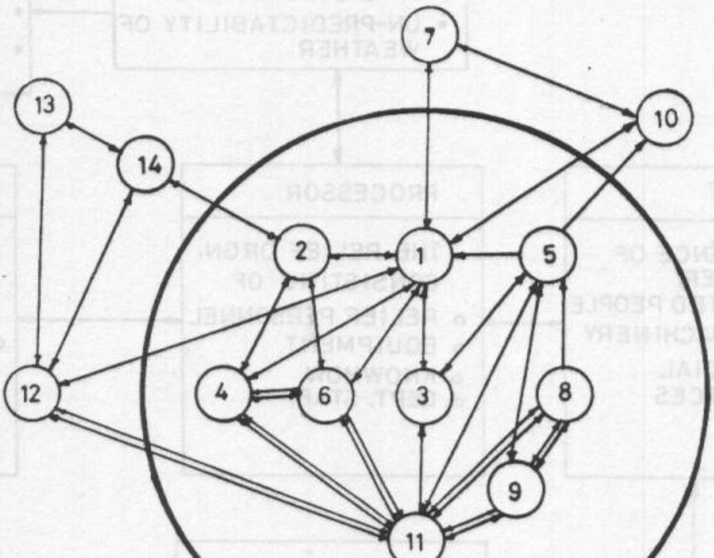


FIG.1. BASIC SYSTEMS DIAGRAM FOR DISASTER MANAGEMENT

FIG.2- SYSTEMS CHART TO DISASTER MANAGEMENT

——— INFORMATION FLOW

═══ MATERIAL AND INFORMATION FLOW



1 TOP MANAGEMENT
2 FINANCE
3 DISTRICT MANAGEMENT
4 MEDICL RELIEF
5 PLANNING CELL
6 TRANSPORT
7 PUBLICITY .

8 MAINTENANCE
9 UTILITIES
10 FORECASTING CELL
11 OPERATIONS
12 CIVIL SUPPLIES
13 CENTRAL GOVT.
14 STATE GOVT.

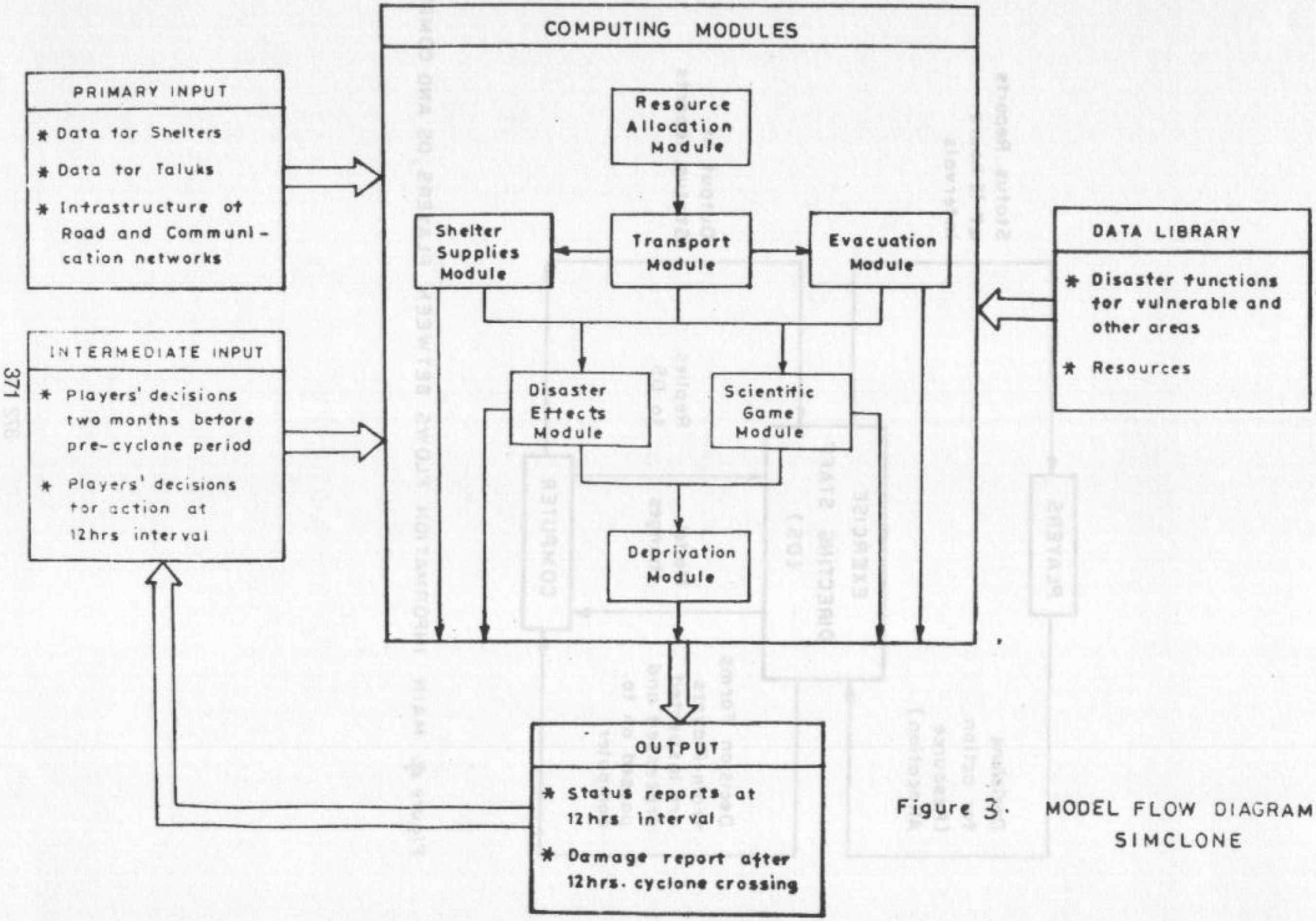


Figure 3. MODEL FLOW DIAGRAM SIMCLONE

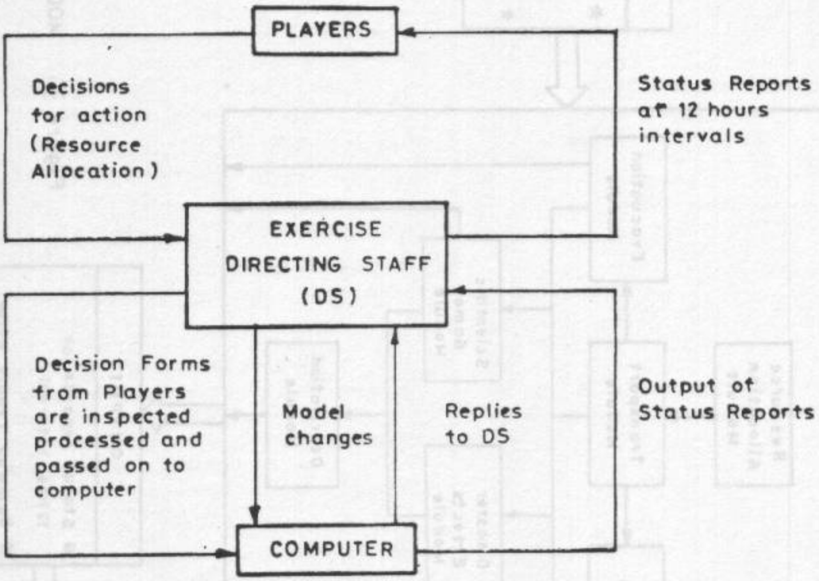


Figure 4 MAIN INFORMATION FLOWS BETWEEN PLAYERS, DS AND COMPUTER

MODELING CONGESTION IN EMERGENCY EVACUATION MODELS

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ABSTRACT

We have been developing a PC based emergency hurricane evacuation planning module, Regional Evacuation Modeling System (REMS), at the University of Florida since 1990 as part of a comprehensive hurricane emergency management decision support system. The software uses simulation as well as several network optimization models in estimating the evacuation time and the traffic flow on a given transportation road network. The system is very robust and user friendly. One of the important features of REMS is its ability to be used in real time. The simulation and optimization models implemented in REMS use different traffic congestion models into the estimation of evacuation times. As part of our ongoing integrated emergency management system development, we are refining and continuously testing congestion models used in REMS. We report some new experimental results that are currently available on REMS for congestion modeling.

1. INTRODUCTION

An ongoing issue in hurricane evacuation modeling is to the following: how does congestion affect the evacuation times?

Quick and accurate answer to this question is very important for the safety of the people being evacuated. In the past, many geographical areas have been ordered to evacuate to find out later that the hurricane did not hit their community. Usually, the hurricane tracking models are more accurate in determining the point of landfall as the storm gets closer to land. Therefore, an accurate estimate of evacuation times provides the needed few extra hours for the storm tracking models to be more accurate in their estimation. However, one should always keep in mind that an under-estimation of the evacuation time will have serious consequences since a good number of people will still be on the road as the pre-landfall hazards start to make travel difficult.

In managing evacuation during a hurricane, it is of paramount importance to estimate the evacuating population and the shelters that will hold the evacuating population accurately. It makes a great sense to establish safe shelters for the evacuating population within the county instead of sending several hundred thousand people on the roads for many miles to travel inland. A good hurricane emergency management system must consider establishing many new safe shelters before resorting to mass evacuation of the population. Providing many safe shelters for the evacuating population will have a dual advantage. Firstly, it will allow people which will be affected by the storm to move to their closest shelter without putting too much burden on the transportation network. Secondly, because of lesser traffic on the roads mostly generated by the transients and some background traffic, the evacuation time for the entire county will be reduced dramatically. This in turn will allow the decision makers to track the storm more accurately and minimize false alarms which is usually common in hurricane evacuation. It is well known that the accuracy of track estimation of a hurricane gets more accurate as the storm gets closer to land. Therefore, this management philosophy of establishing many evacuation shelters and opening them immediately as the storm approaches will have a profound effect in mitigating the dangers and hazards due to hurricanes. This suggested philosophy is in contrast to the existing practices in Florida. Some shelters stay closed during a hurricane if the intensity of the approaching hurricane is below 3 in Saphir-Simpson scale. Due to limited shelter capacity many evacuees naturally travel out of county to find hotels and motels in the neighboring counties inland. This puts undue burden on the transportation network. Excessive load on the roadways make it very difficult to travel and it takes many hours to travel distances normally can be travel in a matter of few minutes.

The accurate estimation of these road delays is of paramount importance to effective hurricane warning and evacuation ordering process. Over-estimation of evacuation times may evacuate an entire coastal community when not needed due to earlier evacuation order and under estimation may leave many evacuees struggling to flee when the wrath of a hurricane such as Andrew or Iniki is upon them.

With the help of REMS one can select among the candidate sites the ones that will serve the purpose of minimizing the total hurricane evacuation time. Furthermore, the software will also provide information as to which road segments will be heavily traveled and potentially become bottlenecks. This will also help planners to be proactive to oncoming storm and allocate necessary resources for managing and controlling appropriate roads and intersections. REMS will also have the ability to update the input data based on the current prevailing traffic conditions. With the help of continuous monitoring of roadways, emerging road conditions may be fed into REMS for analyzing the effects of these conditions on the bottleneck roads and the evacuation times.

REMS is an important component of an integrated proactive emergency management system we are currently developing at the University of Florida.

The current evacuation plans widely used in the State of Florida today are the evacuation studies of a number of different hurricane scenarios evaluated under the population and road traffic conditions of usually 3-8 years old. These studies are usually outdated either due to significant changes in the underlying traffic network and/or due to dramatic changes in the population mix and distribution. Furthermore, most of the traffic flow models used in those studies are not state of the art technology in modeling congestion that exists today. It is very likely that many of the existing evacuation studies which have been conducted several years ago are not valid representation of the reality which exists today.

3. MODELING AREA EVACUATION PROBLEMS

We have presented the process of developing data bases and the evacuation roadway networks in our earlier presentations. For further information of network modeling of area evacuations we refer our readers to [17].

The existing optimization and simulation models (Dafermos and Sparrow 1969, Gibson and Ross 1977, Hobeika and Bahram 1985, KLD Associates Inc. 1990, Sheffi, Mahmassani, and Powell 1981, Sheffi 1985, Sherali, Carter and Hobeika 1991) use one of the two fundamental approaches to allocate the people onto the road network. In one method, the people who reside at a particular origin (centroid) are matched (allocated) with a particular destination (shelter). This allocation process is accomplished by using what is known as the "gravity model" (Sheffi 1985). This model pre-assigns people from an origin to a destination before the actual traffic is loaded onto the road network. It uses the logic that the interchange volume between an origin and a destination is directly proportional to the magnitude of the evacuating people at that origin and the attractiveness of the shelter and inversely proportional to the impedance (distance) between the origin and the destination(see Sheffi (1985) for more details). This is the model used in many hurricane evacuation studies in the State of Florida (Tri-State Hurricane Study Tech. Data Report, and Appendix C 1986, Withlachoochee Hurricane Evacuation Study 1989),and also in some of the software developed for evacuation modeling (Hobeika and Bahram 1985, KLD Associates Inc 1990, Sheffi, Mahmassani, and Powell 1981, Sheffi 1985). The models then proceed to solve the allocation of traffic on the links of the network by using an appropriate model. The models used in this respect are usually either a simulation model or a user equilibrium models as discussed in Sheffi (1985). We call the resultant problem "The Specific Origin-Destination Problem".

Although this method of generating productions, attractions and subsequent trip distribution calculations may be appropriate in regular urban transportation analysis, it usually fails to apply in the case of emergency evacuations. First of all, many of the evacuees do not have any preference as to which particular shelter to go to other than a specific shelter type. Therefore, it is reasonable to assume that they will try to reach to the closest shelter of the type they prefer and settle in the first one with a vacancy. Pre-assigning people to shelters before the analysis seems to defeat the purpose of finding the optimal evacuation pattern which evacuates the people in the shortest possible time. Therefore, models which do not require the pre-assignment of trip tables may yield better evacuation results. In addition, as we shall see later, not restricting the movement of people between a specific origin-destination pair may help reduce the dimension of the problem.

The second group of models do not use any pre-assignment. In contrast, they assign people to their destination as part of the optimal allocation of the entire population on the transportation network. These models are said to combine the trip distribution and traffic assignment simultaneously. There have been a good number of user equilibrium models which combine the trip distribution and traffic assignment simultaneously. One particular network model which has been proposed by Sheffi (1985) also uses user equilibrium in allocating people on the roadways. In this model the transportation network is first augmented with some dummy destination nodes. The number of these dummy nodes equal to the number of types of shelters in the hurricane evacuation study. Each one of these dummy nodes corresponds to a particular type of shelter. Each shelter node in the original traffic network is then connected to its corresponding dummy shelter node via a dummy arc. Assuming O_{rk} represent the number of people who prefer to go to a shelter type k from origin r, this amount now will be assumed to be the origin-destination allocation between origin node r and the dummy destination node corresponding to shelter type k. Once the origin-destination allocations are complete the resulting problem can be solved by using any user equilibrium traffic assignment model. Note that this will produce an origin destination matrix of |O|x4 since there are only four different shelter types in a hurricane evacuation model. For further details on this model see Sheffi (1985).

Sherali and Hobeika (1991) propose another model for handling the trip distribution and traffic assignment simultaneously. In their model they make the number of shelter locations to be opened a decision variable. The resultant mixed integer programming model is then solved by Generalized Bender's Decomposition.

In the specific origin-destination models each origin-destination pair must be handled as a distinct commodity, requiring |O|x|D| many commodities in the corresponding network flow formulation, where |O| represents the number of origins and |D| represents the number of destinations (shelters) , respectively. If, on the other hand, the evacuees are allowed to go to any shelter of their choice, this will produce fewer commodities since there are only four different shelter types in an evacuation study (e.g. hotels/motels, public shelters, neighboring states, relatives' homes). In this case, we will call the corresponding problem as the nonspecific origin-destination evacuation problem.

The final possible modeling technique is when each evacuee is allowed to go to the closest and most convenient shelter. This certainly is the case in building evacuations and may be used for obtaining lower bounds on the area evacuation problems. This approach reduces the problem into a single commodity network flow problem. The problem dimensions get further reduced dramatically in this formulation.

In [17] we discussed extensively the static and dynamic network flow models and their use in congestion modeling. The following table provides the results of 3 Florida counties network clearing times based on arc-LP, arc-NLP, user equilibrium, path-LP and simulation solutions. In this paper we continue reporting further experimental results on these models. For details on these models we refer our readers to [17].

Following each static solution we used our dynamic simulation model to find out how the queues actually will form and what will be the actual evacuation times if we impose the static model solutions on the dynamic network. This is accomplished as follows: given that a static model assigned a flow of x_{ij}^* units on a road segment (i,j) we imposed the additional constraints on the dynamic model which required that the flow on all the time copies of that road segment should be exactly equal to x_{ij}^*

County/Model	Arc LP	Dyn. Sim.	Arc NLP	Dyn. Sim.	User Eql.	Dyn. Sim.	Path LP	Dyn. Sim.
Santa Rosa	4.22	4.43	4.36	4.33	5.60	5.36	4.44	5.4
Wakulla	1.46	1.67	1.51	1.83	1.95	1.83	1.60	1.88
Walton	12.98	12.7	13.08	12.8	12.99	12.7	13.01	12.75

TABLE 1. Results of specific OD models.

County/Model	Arc LP	Dynamic Sim.	Arc NLP	Dynamic Sim.
Jackson	18.56	18.50	18.67	18.5
Hancock	10.29	10.2	10.33	10.2
Santa Rosa	4.43	5.1	4.44	5.36
Wakulla	1.52	1.67	1.61	1.83
Harrison	37.16	36.83	37.23	36.83
Okaloosa	7.91	8.6	8.45	8.7
Walton	13.82	13.4	13.87	13.5

TABLE 2. Results of nonspecific OD models.

We have tested two versions of our models. In one version we assumed the people will select the closest shelter for their travel. We called these model the nonspecific OD models. In the second group we allocated each person to a specific destination and then solved for the best time and route to reach there. We called the corresponding models the specific OD models. The results of our test runs are given in Tables 1 and 2 below.

As we can conclude from these tables, the arc-LP and arc-NLP results are robust and yield very close evacuation times as compared with actual dynamic simulation results. Since the path LP does not utilize the entire transportation network (only those roads on the K shortest paths), its results are more on the conservative side when compared to arc-LP and arc-NLP results. This result was expected. However, the differences were dramatically small and thus making the path LP also a good model in estimating network evacuation times.

6. CONCLUSIONS

We have presented several network optimization and simulation models for the emergency evacuation problem. Results of comparison indicate that all models compare favorably with the established evacuation results taken from the county evacuation reports. The arc-LP and path-LP models are good models for obtaining quick approximations about the evacuation times and establishing bottleneck links. The arc-NLP model turned out to be a nice model to use in estimating evacuation times and establishing bottleneck links. One advantage of this model over the path-LP and arc-LP is its ability to allocate people on more links of the transportation network. Such a solution is much easier to communicate to an emergency manager than the one that predicts only a few roads carrying flow during evacuation. Dynamic network flow model is the most accurate of the models presented. however, due to excessive time requirements of the underlying optimization problem it can not be used very successfully on a PC platform. This is why we use an approximate dynamic model which uses only a small portion of the entire dynamic network and also uses a flow augmentation heuristic in assigning flows to paths instead of attempting to solve a very large size LP problem.

In many emergency evacuation problems the simpler models such as path allocation with linear objective may yield solutions accurate enough to compare favorably with more sophisticated nonlinear multicommodity specific O-D models.

In our follow up study, we will use these models in estimating network clearing times of other counties in the State of Florida. The results from our models will be compared with the current available evacuation result available in Regional Evacuation Reports which use gravity models followed by path allocation techniques of various complexities.

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EMERGENCY MEDICAL SERVICES

THE "ABC SYSTEM": AUTOMATION BARCODES AND CHAOS

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ABSTRACT

Well recognized difficulties in disaster (multi-casualty) incidents, such as registration of patient identity, location, and ability to support medical / management decisions can cause the quality of care to decrease.

In order to preempt these and other difficulties, a computer assisted casualty management plan, part of the major incident plan, has been introduced to make effective use of the Emergency Hospital, a 100 bed, intensive and medium (60) care facility available in the University Hospital Utrecht. This facility is primarily intended for the admission of groups of patients.

This computer network has been developed to register, monitor progress of and care-requirements for any specific patient or for the group as a whole. Medical, nursing and logistical information is recorded with the aid of barcode scanners from prepared tableaus thus avoiding delays. These unique barcoded numbers for representing patients, locations, facilities and treatment groups are used in order to minimize errors. Through communication with the permanent hospital patient databank computer system, all data becomes part of the patient medical dossier.

1. INTRODUCTION

The Netherlands has focused interest on disaster management for decades. As early as 1953, with major flooding of its southwestern islands, interest in prevention of mass casualty incidents, development of emergency services, and in particulair hospital incident plans was reinforced.

In January 1992, the national government has as recently passed new legislation concerning (emergency) medical assistance during such situations [1,2]. Hospitals, though free in determining the specifics of their own major incident plan, must have such a plan. An updated outline of an admission procedure was supplied to all hospitals in February 1992 [3]. Nonetheless, experience and literature sources show that admission procedures remain a 'gray area'. Many workers in disaster management [4] have shown that important (medical) information, needed for triage and decision-making can be lost in the admission process [5].

In order to fully utilize a 100-bed emergency hospital, a computer assisted patient management system was developed, that makes information available centrally and peripherally, maximizes the use of triage, while minimizing information and time loss. The PC based local area network "ABC system" is geared to the logistic management of patients and patient-based information, specifically for groups of patients who may be admitted to a hospital setting in a short period of time. It acts as a satellite to the Hospital Information System. This system has demonstrated a 25% improvement in quality and quantity of information available.

We would like to present this system which has shown itself to facilitate the admission procedure of patients to the hospital and thereby promote the quality of care.

2. CURRENT SITUATION AND PROBLEM DEFINITION

The University Hospital Utrecht, an 890 bed teaching facility, moved to newly built facilities in 1989. An 8000 m^2 area of the ground floor has been allocated to the Ministries of Defense and Public Health, Welfare and Culture (WVC) and refurbished to provide an Emergency Hospital with a capacity of 400 patients.

The Department of Intensive Care and Clinical Toxicology of the University Hospital, which is affiliated with the National Poison Control Center (NVIC) of the National Institute for Public Health and Environmental Protection (RIVM) is located in the Emergency Hospital as an operational unit. This Unit has extensive experience in the treatment of groups exposed to chemical, biological or physical agents [6, 7].

The Emergency Hospital (**Figure 1**) is self contained and is designed to admit and treat 100 patients. It contains a triage and treatment center where flexible subdivisions hold 16 treatment stations. Diagnostic facilities (lab, X-ray and three operating rooms with recovery) are available. For Intensive care/high care 30 beds are arranged in four separate wards, in addition to a 60 bed medium care ward. If needed 300 additional (low care) beds are also available in the Hospital. Separate but adjoining facilities are available for use as waiting rooms and as a temporary morgue. The University Hospital and its Emergency Hospital serve as a primary (level 1) receiving facility for the central Netherlands.

When this Department was asked to accept responsibility for patients in the Emergency Hospital, its Emergency and Disaster Medicine staff members decided to review principal needs.

Examination of the literature showed that mass casualty procedures were not just 'scaled-up' versions of single patient oriented care [5,8]. Criteria concerning diagnostics and the level and scope of maintainance of care needed clear definition [9]. Additional organization of admission procedures as well as medical, nursing, and logistic systems required support by information management. Two items, the use of triage (sorting of patients with respect to required care), and the facilitation of command and control were earmarked as a 'spear-point' requirements and shall be discussed further.

2.1 Limitations

In looking at the objectives of the ABC system (**Figure 2**), two primary items were analysed. These were:

Triage and implementation: In daily practice, as in mass casualty incidents, choices in who should receive treatment (first) are made. To do this, history, examination and treatment results are made available to the physician and nurse who then implement and evaluate the treatments themselves. During mass casualty incidents patients are triaged, assigned an urgency-group (in which all the urgency-1 patients are treated before the urgency-2 patients receive attention) and 'passed' on to others.

This would work fine if the patient cohort arrived in bulk (making comparison possible) and no patient improved or became unstable later (vertical evaluation). The physician who sees all patients - and as such can triage effectively - evaluates at 'the door' to the hospital and expects his instructions to be implemented by others in the hospital. Decentralized information (medical chart) is available, but must remain with the patient.

Registration and locatization of patients: Most hospitals have extensive computer systems and charting procedures to document medical and nursing information. During mass casualty incidents these (often time consuming procedures) break down. Typically, as with

BAZIS, the Hospital Information System used in 60% of the hospitals in The Netherlands, this system supplies subsystems for location, laboratory, financial and text files. These systems work with the patient registration number on a per patient per subsystem level: it cannot document groups and is not programed to follow rapid changes. In (international) practice (medical) information made available to the physician from the prehospital situation is limited; it is typically noted on a "patient tag" [1,2]. Regrettably, these pre-numbered tags allow only 'uni-directional' development of the patient's history [10].
Particularily the processing of patients who have (potentially) been exposed to chemical substances, procedures and registration / charting of patients (who may or may not have been exposed) has been shown to be deficient [11,12].

Analysis of regular practice, exercises with simulation-patients in different regional hospitals and during the eight mass casualty incidents in the University Hospital showed information loss (**Figure** 3) to be a potential difficulty. Due to large floor-areas and the large number of personal involved, command and control also remained a concern [12].

3. COMPUTER ASSISTED CASUALTY MANAGEMENT

The major incident management plan was restructured to correct a number of the problems summarized above. Algorithms were designed to be parallel to or approach normal daily routines [8]. Simple and clear cut limitations and boundaries were defined. Command and control became the responsibility of a centrally located multidisciplinary team. A number of additional aspects of the management of each patient had to be introduced: information concerning the type of patient and a number of specifics about each patient was to be centrally available within seconds after their arrival. An up to date location of each patient should be readily obtainable, as should be the chart. Each patient should be clearly identified (patient registration number) while name address etc. should be available as soon as possible.

In 1993 a dynamic system became available that is capable of identifying and tracing patients, while at the same time assisting in the medical, nursing and logistical documentation of the patients, allowing real time as well as prospective and retrospective analysis of treatment (needs). Information gathered about each patient automatically becomes part of the permanent medical file in the Hospital Information System (HIS).

3.1 The ABC system:

The "ABC" PC based network was developed as an independent satellite system of HIS. It uses one of the UNIX systems with COMZIS (a linking program) to communicatie with HIS and its subsystems such as PATREG (registration), LABZIS (laboratory results) and others. Communication was realised via IEEE-ethernet [13] working with the OSI-model. Physically, the coaxial and fiber-optic cables already in use in the hospitals were employed. The ABC-system has its own server (486-DX, 50 MHz, 16Mb memory, 210Mb HD-capacity), and at least ten user stations (386-DX, 33 MHz, 4Mb memory, 40Mb HD-capacity) (Figure 1: the "•"). The stations also incorporate the command group in the receiving area and the directorate (Board of Directors: responsible for total hospital effects).

With regard to the software, the ABC-applications were written with Nantucket Clipper V. 5.01 and Microsoft C, V 6.00. This choice was made so that communication with HIS (Pascal) would be possible within an environment acceptable to hospital privacy-demands. Records in the database are divided into three parts: General disaster data, Patient data, and Fixed descriptive data.

The general disaster data relates to all patients of a specific disaster: an example is the patients who are all victims of a bus accident. This data will be stored in a text-field in which free text can be entered. This allows the cohort as a whole to be identified.

The patient data relates to one patient. All patient data is linked to a patient identification number and a date-time group. This data is further divided into six categories (**Figure** 4). These are information categories that were already part of the regular medical and nursing charts.

General patient data relates to personal data such as name, address, birthday and gender. Patient location data supplies the previous and current location data, for example in X-ray, of each patient. Patient urgency data describes the medical status of the patient. For example, urgency I indicates a patient whose life is in jeopardy and must be helped as soon as possible. Patient destination data is a combination of destinations and treatments. It indicates expected location(s) and treatment. The complete routing of the patient can be followed by means of the destination data. Patient medical indication data supplies medical diagnosis such as "left pneumothorax". Additional remarks allows free text to be entered, when for example a medical diagnostic code is not available.

The third type of record in the ABC-system is the fixed descriptive data. These define the codes which appear in the patient data, such as location codes, urgency codes, medical indication and treatment codes.

Barcodes: Development of a user-friendly system was one of the tasks assigned. Information-processing should require a minimum of time and be thoroughly reliable; experience with the system could not be guaranteed due to its infrequent use.

This led to interactive and other non-keyboard oriented facilities. No standard was available. In cooperation with "Stichting UAC/Transcom", the Dutch member of the International Article Numbering Association), the possibilities were studied [14] for creating unique numbers in our system for patients, diagnoses, locations and treatment, by utilization of a new identifier in the "UCC/EAN Application Identifier Standard" (**Figure** 5). The use of 128 symbol technique for barcoded alfanumeric information gave the simplicity required. Codes, and patient identification numbers, are applicable internationally (in all EAN countries). This also prompted the use of the WHO ICD-9/10-CM diagnostic codes [15].

In close cooperation with PHI (Woerden NL), which allowed for extensive testing, nine PSC "moving beam hand-held, non contact" barcode readers with nine Intermec wedge readers were purchased.

Patient registration numbers: The 200 patient registration numbers prepared for special situations have been coded to include unique prefixes and suffixes. These numbers correspond to a fictitious name and birthdate, because the automated HIS patient databank requires such data. In this way the different laboratories can use regular channels to 'return' the results. These numbers correspond with preprinted ID-bracelets and medical status folders complete with laboratory and other forms as needed. It also allows comatose patients to be recognized by the use of a defined unique number, while enabling other patients to be recognized with their own names as soon as possible.

Tableaus: Using large sheets a system was developed for representing the barcodes. On these sheets, barcoded information (**Figure** 6) was divided into a number of categories. The urgency codes 1 - 5 were defined, using international standards. Location codes define wards and bed locations. This makes it possible to 'assign' a bed to a specific patient (even before this patient has arrived), and recognition of the use of this bed (i.e. required facilities and personal) while the patient may be elsewhere. It also allows priorities (anticipation) within the patient group by different diagnostic facilities. Medical indication and treatment codes describe the vital signs and (important) types and locations of injuries, as well as treatment begun or expected. In all about 50-60 options are currently available.

3.2 Experience and results to date

During the four occasions on which the ABC system was used registration of data was done simultaneously both in the ABC-system and handwritten in patient charts. This enabled a comparison of manual procedures with the new automated procedures. We found an improvement of at least 25 % [16] when using the ABC-system in the:
- quality of information (301 vs 246 'items' correct);
- quantity of information (318 vs 257 of the 350 'items');
- accessibility (major improvement, questionnaire).

In other experiments it was shown that improvement tends to increase when less registration time is available, that is in more stressful situations.

4. AN EXAMPLE

A patient arrives in the ambulance hall and receives a patient identification number (a bracelet is put on, the medical chart supplied). Here, his identification number is entered along with relevant information from the pre-hospital situation. The first step(s) in his routing is assigned. The hospital administration can 'recognize' his presence (**Figure** 7) and location and can inform (local) government as such.

Assuming that this patient is comatose he remains a number during the first period. In the Emergency hospital a physician assigns the clinical urgency group. This is registered in the ABC system allowing the X-ray department to anticipate on the (high urgency) patient who has just arrived. A patient in the medium care ward will now not be called, but will wait until the patient we are describing has been x-rayed. The Intensive Care notes that an ICU bed has been assigned and can anticipate on the new arrival.

Family, calling the hospital can be informed of the location, urgency and some general information as soon as the identity of the patient is established (generally upon arrival in the wards), using drivers' license etc.

5. CONCLUSION

We believe that the quality of care provided to groups of patients is largely dependent on the ability to control the flow of these patients, the available knowledge concerning priorities set during triage and the follow-up.

In creating this model the registration of patients (without the need for specific identification), diagnostics and treatment can commence immediately using barcoded information. The system also allows different users to be continuously up-dated as to patients who can be expected and the needs of these patients. Important "policy-making" decisions can be made by teams responsible for patient care, logistic support, and hospital administration, thus allowing a high level of care to be provided.

Other applications suggest themselves within regular hospital patient logistics and management, in the EMS under special circumstances, and to identify a patient in such a way that hospital and patient number remain unique.

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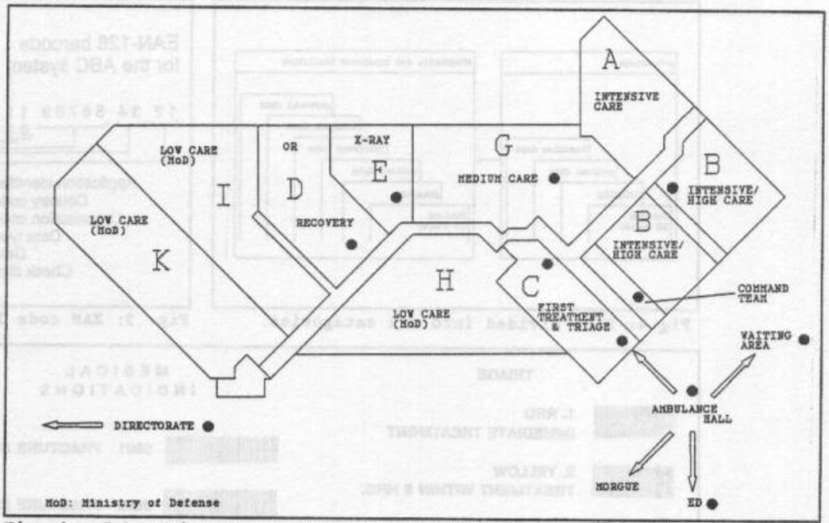

Fig. 1 : Schematics of the Emergency hospital, incl. "●" for the location of the user stations.

- Registration and identification of patients;
- Localization of patients;
- Generating reports;
- Communication between the ABC-system and the HIS;
- Support analyse afterwards.

+ Low-costs in implementation and maintenance
+ Maximum in user-friendliness

Fig. 2: Objectives of the ABC system.

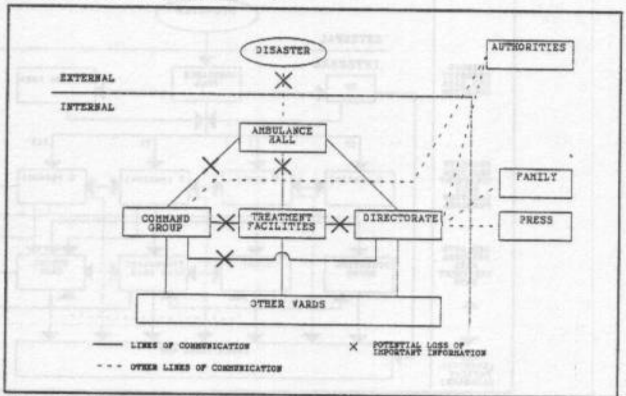

Fig. 3: Potential locations of information loss

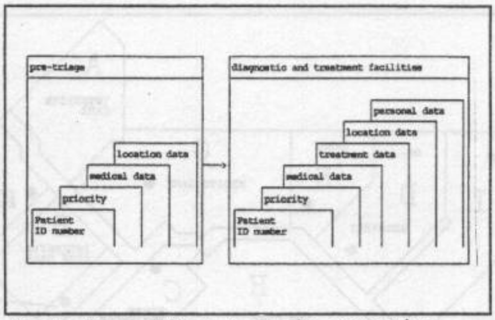

Fig 4: Data divided into six catagories.

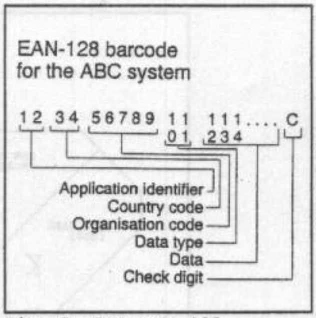

Fig. 5: EAN code 128.

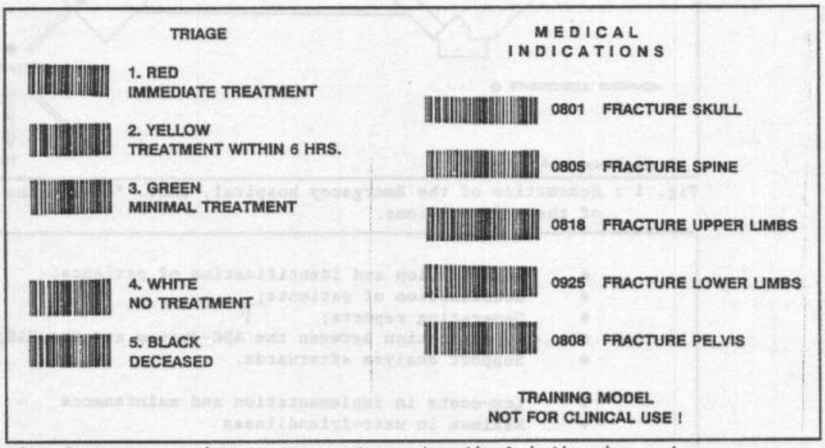

Fig. 6: Tableaus with urgency codes and medical indication codes.

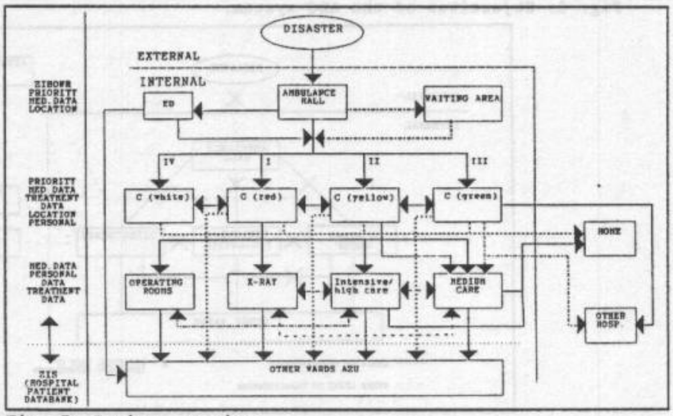

Fig. 7: Patient routing.

INSIGHTS FOR DEMAND FOR EMERGENCY DEPARTMENT RESOURCES, BASED UPON A PROBABILISTIC MODEL

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ABSTRACT

This paper reports a probabilistic model for the demand arriving at a hospital's emergency department, and applies it in order to gain insights into why certain enhancements work and others do not. The full work is reported in [1].

The emphasis in this work is on demand characterization and on demand management, and not on service modeling. The demand is characterized in terms of client (patient) illness categories and emergency department resource parameters, using the literature and a resource group of medical professionals as a base.

The analytic form of the model is used to gain certain insights, and a spreadsheet is used for additional insights. These include comments on the variability of the resource delivery, provision of storage as a means of improving throughput, referral policies by which the demand variability is reduced, and the effects of shifts in the client base. The end result of this is a tool and a set of insights to understand and explain the nature of the demand so that practitioners can see <u>why</u> certain measures are effective. The spreadsheet and results can also provide the mechanism or conversation "enabler" by which training or planning sessions can be held on data planning needs, and on evaluations of scenarios.

1. INTRODUCTION

Emergency rooms are dynamic environments, the nature of the facility being random arrivals with a variety of client needs. The randomness gives rise to scheduling and staffing problems, with great challenges for an operations manager.

Visits to a number of facilities have established that each facility is almost unique, because of variations in the population served, types of emergencies seen, volume of case load, physical layout of the facility, proximity (or not) of supporting services, and other factors. The challenge is to understand when various innovations can be applied, in what combinations, with what success.

The preliminary work has also established that although there is literature on emergency services modeling, it is sparse and (1) most successful innovations were experiments introduced by creative operations managers, and (2) the data base on service times and characteristics is woefully lacking. Moreover, the typical facility manager is overwhelmed by the possibility that data needed for future planning must be very detailed, and that its collection is likely to be intrusive on the provision of health care.

2. LITERATURE

As a result of the analysis of the existing literature and of interviews conducted at ten facilities in the N.Y. Metropolitan Area, several issues have surfaced that illustrate the fundamental findings of both the literature search and of the supplemental visits:

> Item 1: The purpose of the emergency room is being refined in the 1990's and is fundamentally different from the 1950's. However, the recognition level of this evolution varies from facility to facility. Even in the literature, assessments sometimes reflect the older view of the mission of the emergency facility;
>
> Item 2: The need to disaggregate the client population seems to be of growing importance in assessing the demand for resources. Specifically, certain segments of the population (the young, the old, etc.) require different mixes of services, have different services durations and sometimes need specialty equipment sizes or designs;
>
> Item 3: An understanding of the distribution of customer illnesses identified by the population segment affords knowledge of resources needed for a given time of day, week, and season. Such information will serve as an efficient base for the analytic work of this dissertation which addresses the demand put upon the resources of the Emergency Room/Department both in terms of averages and in terms of a probabilistic model.

A matrix for patient illness categories and categories of resources was created through review of references, including those by Jenkens, Loscalzo [2], Gillies, et al [3] and Eliastam et al [4] and through discussions with a resource group of local experts and practitioners. The compilation of client complaints with their clusters of illnesses and array of resources was based on the authoritative medical text of Eliastam et al [4] along with the lengthy discussions held with the panel of experts. Service distributions were estimated in consultation with experts at several facilities visited.

The two dimensional matrix of patient illness and resource categories provides a tool with which to estimate frequency and level of demand for resources and to assist at a later date in the modeling of a 3-ply matrix of population segment, customer illness category, and resources, as shown in Figure 1.

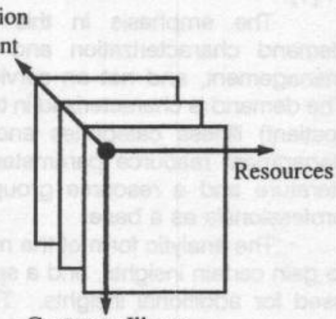


FIGURE 1

3. THE BASIC PROBABILISTIC MODEL OF SERVICE NEED

The basic model does not focus on the efficiency with which the demand is serviced, such as a queueing analysis or simulation might. Rather, it focuses on the "demand for service", its variability, and means of alleviating that variability. Some supplemental queueing modeling is done to address the efficiency with which the demand is processed, but this is secondary to the prime purpose: providing an understanding of the conditions and parameter ranges under which some strategies work and others do not.

Consider that there are N customer/patient demand categories ($i = 1,2,.....,N$) and M services ($j = 1,2,.....,M$). The customer/patient categories might range from cuts to respiratory distress to trauma cases. The resources might range from triage to x-ray to endoscopes. Not all services are necessarily invoked for a given customer category.

a) N Customer Categories and M Services, Poisson Demand The number of customers Y_i which arrive in a given demand category "i" is a random variable, with $Pr(Y_i=y) = p_i(y)$. The number of people showing up to be treated in a given time period can often be modeled as following a Poisson distribution with reasonable accuracy. Each Poisson distribution has mean λ_i. The mean may vary over time, but we will consider it fixed for the time period of the analysis.

For a given category "i", the patient is provided a set of resources ($j=1,2,...,M$), the duration of each of which is a random variable. The mean, variance, and distribution of the duration differs with both "i" and "j". The probability density distribution of the j^{th} resource for the i^{th} customer group is denoted $f_{ij}(t)$ in this work. The corresponding random variable is denoted T_{ij} in what follows.

Let ST_{ij} denote the "time need for the resource" for all Category "i" who arrive on the shift (i.e. the analysis period) needing resource "j". Because both the number of arrivals and the durations are random, it is clear that the ST_{ij} are also random variables.

If there were exactly "y" customers of the i^{th} type, the demand for resource "j" would have a distribution $g_{ij}(t|y)$ which is simply the convolution of $f_{ij}(t)$ with itself "y" times. This is so because the random variable $ST_{ij} = T^{n=1}_{ij} + T^{n=2}_{ij} + \cdots + T^{n=y}_{ij}$ where the "n" denotes individual customers, from n=1 to n=y (i.e. individual samples from the $f_{ij}(t)$ distribution).

Because $g_{ij}(t|y)$ is the result of a convolution of the same distribution with itself several times, the Central Limit Theorem can be invoked and we can say that $g_{ij}(t|y)$ is normal with mean $y\mu_{ij}$ and variance $y\sigma^2_{ij}$. This is only valid for larger values of "y", the number of customers. However, as long as the $f_{ij}(t)$ are relatively smooth, the normality of the $g_{ij}(t|y)$ can be used in practice, even for small "y".

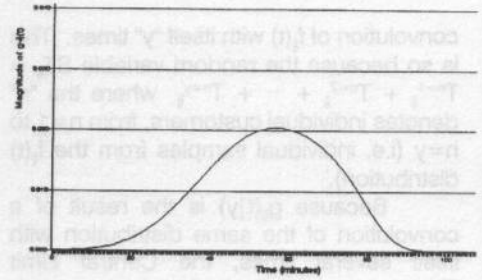
For those cases in which the "y" is too small and the $f_{ij}(t)$ too sharply defined, the next step will minimize the effect. *The net result is that the exact form of the $f_{ij}(t)$ distribution is rather unimportant, and they can be characterized adequately by their mean and variance.*

The distribution of $g_{ij}(t)$ is another matter, however. It is not simply the sum of several random variables. Rather, it takes on several different shapes, depending upon the number of customers "y". It is the composite of these shapes, weighted by their relative probabilities; let $P_r(Y_i = y) = p_i(y)$. Therefore,

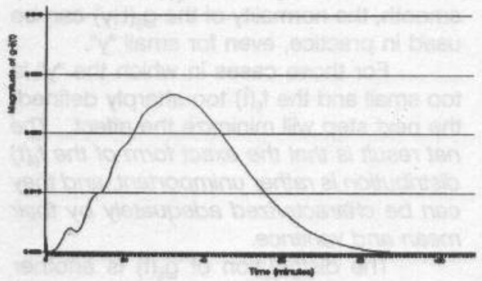
$$g_{ij}(t) = \sum p_i(y)\, g_{ij}(t|y)$$

where the summation is over "y". Further, the summation is for $y \geq 0$, so that there is a concentration of probability at $y = 0$. The $g_{ij}(t)$ is the simple addition of the weighted components (multiply each $g_{ij}(t|y)$ by its corresponding $p_i(y)$ value and then add).

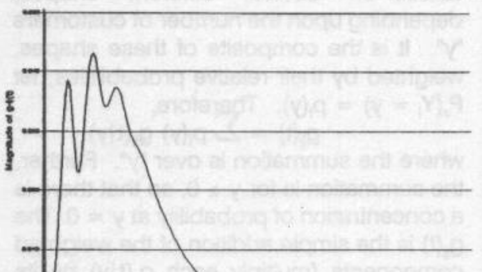
Depending upon the relative values of the means μ_{ij}, variances σ^2_{ij}, and the demand distributions, the resultant ST_{ij} distributions can be rather smooth (Figure 2a), show some irregularity (Figure 2b), or have pronounced irregularities (Figure 2c). These cases are all shown for Poisson demand, with various λ_i and $\mu_{ij} = 6$



a) High Demand (λ = 10); Rather Smooth Curve



b) Lower Demand (λ = 6); Some Irregularities



c) Low Demand (λ = 3); Pronounced Irregularities

FIGURE 2
DIFFERENT ST_{ij} DISTRIBUTIONS, DEPENDENT UPON DEMAND FOR VARIOUS λ_{ij}, WITH μ_{ij}=6 AND σ_{ij}=1.6

minutes, σ_{ij} = 1.6 minutes.

After some reflection, it is clear that the irregular distributions occur when the component distributions do not overlap.

Note that the tail is relatively smooth even in Figure 2c even though the principal components are not, because the $\sigma_{ij}\sqrt{y}$ are larger compared to the step; for y=10 and σ_{ij} = 0.7 minutes, the $\sigma_{ij}\sqrt{y}$ = 2.2 minutes and the even the "2σ" spread is ± 4.4 minutes about the center of $y\mu_{ij}$ = 10(6) = 60 minutes for this value of "y", thereby overlapping the y=9 and y=11 distributions (with the $p_i(y)$ providing further tapering).

b) Convolution to Generate the Resource Need Distributions TT_j The ST_{ij} distributions are not the total measure of demand for a particular resource, but simply components of that demand. Define TT_j as the total demand for a resource "j", and note

$$TT_j = \sum ST_{ij}$$

where the summation is over "i", the various customer categories.

Let $h_j(t)$ be the probability density function associated with TT_j. It is the result of a convolution of the $g_{ij}(t)$, for each of the N "i" terms. The mean and variance of TT_j is simply computed in terms of the ST_{ij} means and variances, assuming independence.

The convolution of the ST_{ij} does not result in a simple invocation of the Central Limit Theorem in this case, however. The ST_{ij} distributions are each different from the others, and it is not at all a case of adding several identical distributions. The TT_j is not necessarily normal, although it is frequently smooth and appears to be normal. The smoothness can occur because the summation (i.e. the convolution) has this effect.

Although the TT_j distribution is frequently smooth, it is also true that it often has a tail, due to the long tail on one or more of the component ST_{ij}

distributions. At the same time, the TT_j and the comparable normal often match in the upper tail, even if they do not for lower values. The match in the upper tail has an interesting implication: decisions made based upon the 95th percentile point would not be far wrong if the normal distribution were used.

4. SUPPORTING COMPUTATIONAL TOOLS

In order to explore the implications of the above formulation, and to investigate ranges of parameters, a set of programs were written and interfaced with both a spreadsheet and a graphics package. Much of the same analysis could be done in spreadsheets, although it is not as convenient to accommodate an arbitrary $f_{ij}(t)$ distribution. A spreadsheet implementation leading to the $g_{ij}(t)$ was done for Poisson customer arrivals and normal $f_{ij}(t)$; it could be easily adapted to non-Poisson demands, and adapted with more difficulty to other $f_{ij}(t)$. This spreadsheet was used for extensive analysis of cases to gain insights.

Some additional spreadsheets were prepared for comparisons of two different parameter set analyses. Reference [1] contains the spreadsheet for a full implementation of the sixteen client categories and twenty-five resources cited.

5. SUPPORTING ANALYTIC WORK: μ_{TTj}, σ_{TTj}^2

Exercising the programs reinforced the early perception that there are too many parameters for efficient insights, whether by computation or by simulation. The parameter sets to consider include:

The number of customer categories, N;
The number of resources, M;
The demand rates, λ_i;
The mean service duration times, μ_{ij};
The service duration time standard deviations, σ_{ij}.

This does not even address the questions of the work flow and the queueing as patients are actually processed, which is not within the scope of this paper.

Rather than design a "complete block" simulation experiment over these parameters, and then search for insights, it was decided to pursue additional analytic development. The insights gained into the shapes of $g_{ij}(t|y)$, $g_{ij}(t)$, and $h_j(t)$ were used to focus on the expressions for mean and standard deviation, rather than distribution shape.

Reference [1] contains the derivations for the mean and variance of the ST_{ij} and the TT_{ij}. The relation for μ_{TTj} is:

$$\mu_{TTj} = \sum_i \mu_{ij}\, \mu_{Cust\,i} \qquad (1)$$

This states that the various results should be added up in order to determine the total average demand for service.

The variance is:

$$\sigma^2_{TTj} = \sum_i \{\sigma^2_{ij}\, \mu_{Cust\,i} + \mu^2_{ij}\, \sigma^2_{Cust\,i}\} \qquad (2)$$

The simplicity of these relations provides us with a powerful tool, which will actually drive much of the analysis.

In many cases, it is the second terms which dominate. The overall variance is caused by the <u>product</u> of the uncertainty in the demand ($\sigma_{Cust\,i}$) and mean service time (μ_{ij}). This is where attention must be focused. Of course, the overall analysis is complicated by the fact that several such terms are added to obtain the variance of TT_j.

Equations 1 and 2 are used in the spreadsheet "COMPARE".

a) Special Case: Poisson Demand

The above derivations were done for an arbitrary demand distribution. Further, they did <u>not</u> make use of any assumption on the normality of the $f_{ij}(t)$; these distributions were also of arbitrary form.

If the arrival demands can be

characterized by Poisson distributions, some special forms of Equations 1 and 2 result:

$$\sigma^2_{STij} = \lambda_i \{\sigma^2_{ij} + \mu^2_{ij}\} \quad (3)$$

and

$$\sigma^2_{TTj} = \sum_i \lambda_i \{\sigma^2_{ij} + \mu^2_{ij}\} \quad (4)$$

This shows that the $f_{ij}(t)$ contribute primarily through their means, not their variances (unless there is exceptional variability in the service durations, compared to the means).

b) Insights From the Analytic Formulation Equation 4 for the Poisson arrivals may also be rewritten as

$$\sigma^2_{TTj} = \sum_i \lambda_i \mu^2_{ij} \{1 + CV^2_{ij}\} \quad (5)$$

where $CV_{ij} = \sigma_{ij}/\mu_{ij}$ is the coefficient of variation. It is reasonable to expect $CV_{ij} \leq 0.20$ in most cases, so that the term in the brackets is generally less than 1.04. This emphasizes the importance of the $\lambda_i \mu^2_{ij}$ terms, and the reality that improvements to the σ_{ij} have little benefit in most cases: they do not contribute to the mean μ_{TTj} at all, and are generally negligible in σ^2_{TTj}.

The coefficient of variation for the TT_j can be written as

$$CV_{TT} = \sqrt{\frac{CV^2_{11}}{\lambda} + \frac{\sigma^2_1}{\lambda^2}} \quad (6)$$

where CV_{11} is the coefficient of variation of the $f_{ij}(t)$ distribution for $i=1$ and $j=1$, and where σ^2_1 is the variance of the customer demand.

Clearly, if $\sigma^2_1=0$, then the two coefficients of variation are directly proportional, and CV_{TT} is inversely proportional to the square root of the number of customers.

Just as clearly, whenever σ^2_1 is significant compared to the mean number of customers, the second term in Equation 8 quickly dominates <u>and</u> drives toward an asymptote determined by the σ^2_1/λ ratio.

What emerges is an illustration of the relative importance of different terms, under different conditions. Of course, if the effects of two customer categories with different ratios were considered concurrently, additional complexities are introduced.

It is also important to recognize that a stable CV ratio is not sufficient. Consider the scheduling of people or machines to meet the demand: both people and demand come in integer quantities. Even if CV is stable, the σ increases in proportion to the number of customers.

As the variance of the demand increases, the resource duration <u>needed</u> also increases. Clearly, as the demand becomes more uncertain, it might be necessary to bring on more staff or more equipment, simply to deal with the uncertainty.

At the same time, increasing demand generally decreases the <u>relative</u> variability. Nonetheless, the absolute variability grows. This is a situation in which the number of staff or equipment required becomes more uncertain on a fixed scale, despite being a smaller percentage problem.

Can an emergency department cope with more uncertainty because it is a smaller percentage of the business? The best answer is, it depends. Certainly it might be a surprise for some administrators to find that an uncertainty of ±1 person becomes an uncertainty of ±2 persons when the business goes up by a factor of four.

6. CASE STUDIES

Three case studies were considered in the complete work [1]:

1) the variance of TT_j is studied,

specifically in terms of the contributing factors;

2) the effects on the needed resources, when the population using the facility shifts, or when facilities in different areas (with different clientele) are considered;

3) the strategy of referring certain overflows to other facilities, thereby making the demand more regular at least one of the facilities, and the effect on both (or all) of the participating facilities.

From Equation 4, the point has already been made that σ^2_{ij} is generally negligible compared to μ^2_{ij}. Rather than it mattering that the σ_{ij}/μ_{ij} ratio is 0.20, substitution allows Equation 4 to be re-written as

$$\sigma^2_{TTj} = 1.04 \sum_i \lambda_i \mu^2_{ij} \qquad (7)$$

Simply put, the σ_{ij} simply do not contribute and their specific values are virtually irrelevant in this case.

Notice that if the μ_{ij} were all comparable, then that term could be taken out of the summation in Equation 9, and made a coefficient. The principal term would then be $\sum_i \lambda_i$, and the σ_{TTj} would be driven by this term.

What are some of the insights from these case studies?

From the first case study, three points: (1) the σ_{ij} simply do not contribute in the typical situation encountered, so that undue attention to decreasing them simply does not make sense; (2) the randomness of the Poisson demand shows up in the CV_{TTj} with full force, and any effort in mitigating the randomness of the input demand has significant benefit; (3) any resource which has one or more μ_{ij} which "stand out from the crowd" contributes directly to the CV_{TTj} and must be reviewed --- particularly if it is multiplied by a significant λ_i.

The real issue in this last point is that any $\mu^2_{ij}\lambda_i$ term which is a significant part of the variance term σ^2_{ij} or dominates it must be addressed. On the other hand, terms which are so small that they "hide" amongst much larger terms need not be addressed at all, unless in concert with sets of such terms.

In the second case study, for minor shifts from a "typical" population to a heavier representation of "older" people with greater frequencies in some categories, there were increases in 20 of the 25 resource categories, representing an average percent increase of 14.3% within those experiencing an increase, and a total of 8.9% increase in needed service-hours for the same total number of patients. Of course, in addition to the shifts themselves, in most organizations a decrease in need within four categories (one had no change) does *not* result in an immediate shift in support of the 20 resources experiencing growth. This institutional reality exacerbates any problems which occur due to a different or changing clientele profile.

Needless to say, as the nature of the resource need changes, the facility must evolve. A number of redesigns are simply attempts to catch up, in one step, with past clientele changing patterns. The COMPARE sheet is one tool which can aid emergency department operators and designers articulate these changes, recognize them, and adjust.

The results of the third case study are more complex to present, and are to be reported in the literature separately.

7. CONCLUDING REMARKS

In the course of this work, it became clear that there is no real consensus on the client categories, nor on the estimates of the resource duration estimates, nor even on the major groups into which the population should be disaggregated. The very existence of a framework (i.e. the "COMPARE" spreadsheet) with labels and numbers will surely (a) make the assumptions clear and open to easy refinement, and (b) generate the discussion leading to such refinement.

The author is also satisfied with the insights gained by using the analytic formulation as a tool. Simulation, which can be a valuable tool, is sometimes used as a brute force approach. Innumerable runs would have been needed to "reveal" the relationships and sensitivities reported in this paper.

These lessons become more complicated to apply, and the effects more subtle, when several customer categories with significantly different resource needs are present at the same time. Nonetheless, they are valid, as could be seen in the case studies in [1].

One of the products of this work is a conceptual framework, namely the linkage from the disaggregated demand and the resource descriptors $f_{ij}(t)$ to the total needs for resources. This was the product of many discussions and reviews. It became clear that the framework itself --- implemented in the "COMPARE" spreadsheet --- was an effective vehicle for focusing the discussion.

Rather than the conversations diverging based upon different perspectives, people with disparate backgrounds found common ground: Are the client and resource lists detailed enough? Are important cases covered? Are the μ_{ij} and σ_{ij} reasonable? Are the results relevant?

The author found that discussions focusing around the set of resources needed, particularly in the face of a changing customer base, freed people to address these questions and start volunteering alternate scenarios (What if this happened? What about that?). Clearly, the spreadsheet became an "enabling technology" for people to focus on quantitative exercises they had previously found cumbersome or did not fully conceptualize.

Therefore, it is planned that in later work the spreadsheet will be used as the tool by which one or more teams address the underlying assumptions (which are explicit, even obvious) in workshops and/or focus groups.

It also became clear that the spreadsheet can be used to train or "bring up to speed" people who are uninitiated in thinking about trends, future planning, and redesign. This can be done in the format of a one-day training course, with worked problems.

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An Integrated Information Architecture for Rural Emergency Medical Service Systems

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Abstract

Rural emergency medical service (EMS) systems presently handle over 12,000 patients per day in the United States. Every patient encounter is information intensive and the capture, processing, and storage of this data is a costly part of the health care delivered. Present approaches for dealing with pre-hospital information are fragmented and unstructured. However, a confluence of existing and emerging technologies offers an opportunity to deploy an integrated information architecture to address the needs of rural EMS. This paper traces the historical evolution of rural EMS information architectures and proposes an improvement based on existing and emerging technologies.

INTRODUCTION

The provision of medical services in the pre-hospital environment is an information intensive activity performed by Emergency Medical Service (EMS) systems. Since their inception over two decades ago, the information architecture associated with EMS has undergone significant changes. The term "EMS information architecture" is here meant to define the communication and computer systems that manage and manipulate information generated in the pre-hospital environment. These have always involved mobile communications as a core part of the architecture. Of special interest is the provision of emergency medical services in rural areas. As many as forty percent of the medical emergencies in the United States occur in "rural" areas. For the purposes of this paper, any area lying outside one of the traditional Standard Metropolitan Statistical Areas (SMSA's) is considered rural. Unlike its urban counterparts, the "rural" EMS system must deal with a service area that possesses large variations in population densities, wide geographic separation of receiving hospitals, and meaningful numbers of patient transfers to facilities outside its primary service area.

Rural EMS delivery systems have existed for over two decades in the United States. Prior to 1970, emergency medical service was provided by a spectrum of entities including funeral homes, garages, and hospitals. Because of this association with federal largesse, EMS was viewed in the 1970's as a "public service" rather than as a part of the health care industry. During its second decade of existence EMS, with the demise of federal funding for system development and expansion in the early 1980's, began to make the painful transition to a market driven environment. As a result, entering its third decade in 1994, most successful rural EMS operations of the 1990's are based on market driven, fee-for-service models. The shift in rural EMS from a public sector, cost-center model towards a quasi-private sector, profit-center model has driven the evolution of information architectures deployed by rural EMS systems.

The discussions of information architectures for rural EMS systems here will follow the historical pattern. First, there will be a perspective of the "past", the decade from 1974 to 1984. Second, there will be a description of the "present", the decade from 1984 to 1994. Third there will be a projection of the "future", the decade extending from 1994 forward. In each case, the design requirements, the system implementations, and performance constraints of the information architectures will be reviewed. The orientation for review will address information as its relates to the operational, business, and medical aspects of EMS

THE PAST IN RURAL EMS

With the enactment of the EMS Systems Development Act in 1974, rural EMS delivery began an evolution from an *ad hoc* component of public safety agencies to a systematic entity for prehospital medical care. A guiding theme of the first decade was to provide rural areas with universal access to standardized protocols of prehospital care. Rural EMS systems operated as two-tier systems of care: Advanced Life Support (ALS) treatment in a mobile environment to deal with life threatening situations and Basic Life Support (BLS) treatment to deal with medically necessary, routine transport of patients. EMS was challenged to develop and deploy protocols and interfaces to the larger health care system.

Past Requirements

Requirements for information architectures in rural EMS systems may be logically divided according to the source and or use of data. Thus one may address business data, operational data, and medical data. The artifacts used to implement the requirements are traditional paper forms, mobile telecommunication systems, automated data processing technology and the protocols integrating these elements.

In the first decade, requirements for the business data processing were minimal. Many rural EMS systems were operated by public agency cost centers and did not bill patients. Insurance carriers were slow in establishing reimbursement procedures. Business data processing and billing remained a system of little concern to rural EMS.

The requirements for operational data and data processing were driven by PL 93-154. One, there had to be a wide area mechanism for <u>reporting</u> or accessing the rural EMS provider. Two, there had to be a means for controlling or <u>dispatching</u> the emergency vehicle fleet in a mobile environment. Third, there had to be a systematic capture for retrospective analysis of the operational parameters associated with each run or service call. The dataset of operational parameters was undefined except to the extent that such data collected could be used to demonstrate adequate access and response times.

The requirements for medical data were driven by the medical practice acts of the separate states in general and the paramedic enabling legislation in particular. A key concept was that of <u>medical control</u>. Under requirements promulgated by DHEW and many state medical practice acts, physicians were always to exert direct, real time control of paramedics in the field. Documentation and data from the field needed to demonstrate medical control and <u>care coordination</u> while describing the time sequence of treatment procedures and patient vital signs.

Past System Implementations

The business data processing cycle of most rural EMS systems was *ad hoc* and viewed as a nuisance. <u>Reporting</u> was accomplished by 911 systems in areas with population concentrations and by area wide 1-800 numbers for sparsely settled areas. Centralized <u>dispatching</u> was implemented using VHF in the 155 Mhz band. <u>Care coordination</u> was to be implemented using a separate UHF (SERS in the 450 Mhz band) system that supported full duplex operation and EKG telemetry. <u>Medical control</u> documentation was based in large part on the Standard Patient Report developed at the University of Pittsburgh that provided a comprehensive operations dataset, prehospital medical dataset, and forward/backward links into hospital emergency departments. Batch analysis of the Patient Report form constituted the operational evaluation.

Past System Performance

Wide area 1-800 numbers proved impractical to market so much reporting in rural areas depended on cross band links with criminal justice and other public safety agencies. Despite occasional channel contention and skip problems the 155 Mhz band VHF systems proved inexpensive and adequate in the dispatch role. The separate UHF system for care coordination and medical controlled proved unworkable and, in the end, unneeded. The cost coverage advantage of VHF was four to five to one over that of UHF. Rural systems could not afford the UHF systems. Although they received relief from the FCC to employ 155 Mhz VHF systems for EKG telemetry, most rural EMS systems had long since shifted to standing orders for medical control by the early 1980's. The Patient Run Report developed at Pittsburgh with minor local modifications was widely deployed and served as the basis for a uniform prehospital medical record.

THE PRESENT IN RURAL EMS

With the demise of virtually all federal support for research and development, rural EMS delivery, beginning *circa* 1984 evolved from tax supported agencies of local government into market-driven, quasi private providers of prehospital medical care. In this second decade, because of the lack of public resources, rural EMS developed a variety funding sources including third party payers and various subscription strategies. Rural EMS systems, in an effort to optimize cost and quality of service, moved to single tier systems of care. For reasons related to cost, quality, and levels of third-party reimbursement all ALS(Advanced Life Support) became the norm. Now as a full partner of the health care system, rural EMS experiences many of the same management and policy problems as does the larger health care industry. The aging of the population continues to escalate the demand for services. The highly litigious nature of the general society requires greater emphasis on service quality and patient documentation. The requirement of EMS systems to provide emergency service on demand without regard for the ability of the patient to pay in a population that is increasingly under-insured or uninsured places great stress on the operational aspects of financial management.

Present Requirements

In the second decade, requirements for business data processing were expanded significantly and tied directly to the prehospital medical record. To effect patient and third-party billing, it was necessary to capture complete financial data, to demonstrate medical necessity, and to automate the billing cycle. The reporting requirements were usually met by the arrival of enhanced 911 systems. The dispatching function embraced a more expansive role involving arrangements for institutional transfers, payment processing, and resource allocation. From a logistical standpoint dispatchers were required to validate institutional arrangements in all patient transfers and with the business office/function arrange payments for non emergency transfers. From a fleet standpoint, dispatchers were expected to provide system status management so as to meet performance targets within existing system resources. The requirements for medical and operational data were increased to address the ever present threat of litigation, the need for quality assurance, and the demonstration of necessity. Care coordination required extensive documentation and review for appropriateness.

Present System Implementations

The business data processing cycle of all rural EMS systems, taking advantage of the microcomputer revolution was automated. Reporting was accomplished by enhanced 911. Centralized dispatching continued its reliance on earlier VHF systems in the 155 Mhz band augmented by local cellular systems. For larger rural systems Computer Aided Dispatch (CAD) systems were deployed. Care coordination was handled by standing orders. Medical control documentation was expanded and the state reporting requirements for both operational and medical data exploded. Every region or state sought to define its own unique prehospital medical record based on a paper model.

THE FUTURE IN RURAL EMS

With the pending reorganization of health care delivery in the United States likely to begin in 1994, rural EMS is due for yet another major shift in medical and financial paradigms. While the nature of health care reorganization is yet to be debated, rural EMS , in its third decade, can expect significant changes in funding and delivery mechanisms. A likely funding mechanism is a shift from multiple payers on a fee-for-service basis to single payor, single payment reimbursement tied to demographics. The role of personnel and the menu of medical services offered will also change dramatically. In rural settings without hospitals, EMS may emerge as major player in primary care and preventive health programs. Patient documentation and linkage needs will explode and the pressure to optimize the cost of production while maintaining quality will be dominant.

Future Requirements

First generation rural EMS information architectures could be characterized as an attempt to observe the system, second generation as an attempt to control the system, and the next generation as an attempt to optimize the system. Reporting, although generally implemented by enhanced 911 technology, will have to accommodate increasingly larger service areas as the aggregation of rural EMS providers continues. Whether operating under a market driven or managed competition motif only the strong will survive. This will dictate the real-time integration of business constraints, operational data, and patient medical data for decision making. The logistics of what is now termed "system status management", now simplified by single tier delivery systems, will have to incorporate the concept of "economic dispatching" in a multiple tier service environment. The current concept of the prehospital medical record as defined by various state regulators will have to be expanded to include intelligent mechanisms to gauge the necessity and appropriateness of care protocols while incorporating electronic portability. The information architecture of the coming decade in rural EMS must integrate all medical, economic, and business data while allowing ubiquitous access for machine-aided decision making by those closest to the delivery of services.

Future Info Architectures

Previous information architectures in rural EMS could fragment the business, operational, and medical data. That fragmentation is no longer allowable. Because of the nature of data involved, the following platform needs exist for the next generation system. On the communication side there is a need for a ubiquitous, broadband mobile capability. At least the system should allow some dynamic allocation of bandwidth. On the computer side there is a need for a multimedia data repository with distributed access from either fixed or mobile sites. The means of data capture should be highly automated and occur as close to the source as feasible. The supporting software must include intelligent decision making aids for vehicle/resource deployment over time, appropriateness of medical procedure, economic dispatching, and documentation extensions in higher risk procedures. Depending on the new paradigm for health care the decision making on economic dispatching and appropriateness of care may require access to data created by other health care providers.

The inexorable march of technology now places many of these capabilities in reach. The Motorola Iridium and other competing approaches should make available with utility pricing in this decade a ubiquitous mobile telephony capability for rural EMS that integrates terrestrial and space cellular seamlessly. The economies-of-scale in the broader computer market make local-area-networks (LAN) an attractive means for enterprise wide, missions critical applications if reliable, broadband communications can be obtained in the mobile environment. Relational database technologies now exist for multimedia data management on the platforms of choice. Neural network technologies afford a new, heuristic decision tool of great promise in health care.

The key driver of this this integrated information architecture, however, are the new paradigms for health care delivery emphasizing managed care with life cycle costing. Although the shape of these paradigms remain to be determined it is reasonable to expect that by 2000 the rural helath care delivery system will be an integrated one in which EMS will assume some of the tasks associated with primary care. The information architecture for rural EMS accordingly must become integrated and support decision making with the totality of system and patient data. The architectural requirements overviewed here are structured in that direction.

CHEMICAL EMERGENCIES

A PROJECT VIEW OF EMERGENCY RESPONSE

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ABSTRACT

The proper management of emergencies is virtually synonymous amongst practitioners in the field with proper management of response. Emergency response is marked by high saliency, time urgency, and uncertainty. Emergency response has critical attributes in common with project management.

This paper defines the authors' experience in the application of classic project management techniques to response plan evaluation. Through the use of simple computerized project management techniques, a clear picture of the effectiveness of emergency response is possible. The information from this response modeling is quantitative and provides direct guidance in modifying plans.

The authors have applied project management techniques to an analysis of emergency plans around chemical weapon stockpile sites in the continental United States. Of the eight chemical weapon stockpile sites, plans for six have currently been evaluated. The analysis has been found to be a tool of considerable use in identifying areas for further modification.

INTRODUCTION

Innovative Emergency Management, Inc. (IEM), is helping the Chemical Stockpile Emergency Preparedness Program (CSEPP) review emergency plans through an effort termed Systems Analysis. There are eight sites in the continental United States where chemical weapon stockpiles are stored. These weapons are expected to be destroyed over the next few years at onsite chemical destruction facilities. Disposal operations are expected to start in 1995 at the first such facility, at Tooele Army Depot (TEAD).

The CSEP program goal is to mitigate effects of any possible accidents.[1] To support this goal, resources and guidance have been provided to all eight stockpile locations, including the Army installations, surrounding counties that are included in the defined Emergency Planning Zones (EPZs), and the ten states that are included within the bounds of the EPZs. A major initiative in the program has been the development and evaluation of emergency plans for potential accidents or incidents involving chemical weapons. Emergency plans at each stockpile site generally include Army depot Chemical Accident and Incident Response and Assistance (CAIRA) plans, EPZ county plans, and State(s) plans. These plans form the cohesive system to meet the goal of mitigating effects of an accident.

PLANNING FOR EMERGENCY RESPONSE

The goals of any emergency management can be quickly recounted by the practitioners and the researchers in the field alike: save lives, protect property, minimize disruption. The order of these is significant also. In cases where there is a threat to life, saving lives inarguably is the primary goal of emergency management.

Emergency managers attempt to achieve the goal of saving lives through detailed planning. However, since emergencies happen infrequently and unpredictably, there is limited opportunity for emergency managers to learn from direct, personal experience. There are three major characteristics of emergencies that tend not to be addressed in emergency response plans in general, and in CSEPP plans in particular.

Emergencies are generally associated with a sense of urgency. Decisions need to be made and actions taken within limited time windows. Although there are slowly-developing hazards such as drought, the vast majority of the more common hazards are marked by time pressures. Technological hazards in particular have specific characteristics that have temporal repercussions. Technological hazards are generally associated with rapid speed of onset, no or little forewarning, and high severity of impact. The net result of these attributes is a need to have the protective actions implemented quickly. If response is not swift enough, planning before the event is virtually useless.

Emergencies demand that responders perform tasks that are highly interrelated. Effective coordination between tasks is essential because the actions in each function involved in emergency response can have a dramatic impact on the performance of other functions. Emergency response is a system. Without a recognition of the high degree of interdependence between parts of the system, one function may be performed in a way that meets its own functional goals very well, yet hurts the performance of other functions that are dependent on it.

Emergencies are characterized by uncertainty. The extent of uncertainty can be higher in technological hazards. With a flood or a hurricane there are predictive factors, some forewarning. With most hazardous materials incidents and other technological hazards, there is considerable uncertainty about what may have occurred already and how it could escalate.

Although planning has been a central activity in emergency management, the relationship between planning and response has been tenuous. The primary product of planning is an emergency plan. There is no direct and mapped process for the use of plans during response. Most plans are written in a format that does not allow quick usage during response. In addition, the plans that the authors have reviewed for the Systems Analysis typically do not account for the time pressure, task interdependency, and uncertainty likely in a response to a chemical stockpile disaster.

EMERGENCY RESPONSE MANAGEMENT AND PROJECT MANAGEMENT: A COMPARISON

Rigorous project management techniques were developed during the World Wars. Gantt charts, PERT charts, and formal operations research were created to meet the needs of large, complex military projects. These techniques have since been widely applied to fields other than defense, such as construction and general management of business projects. Using such tools, businesses have been able to manage large, complex endeavors and ensure that products and services are produced in time and within resource limitations. The requirement for project control using rigorous, quantitative techniques is almost universal in general business and government.

Specific characteristics separate a project from general activities performed by an organization. These attributes of projects are directly comparable to the attributes of emergency response. A comparison of project management and emergency response attributes is shown in Table 1.

Projects and emergency response both have boundaries in time. Emergency response does not have a pre-specified start date. But it does have a specified starting event (an indication or an actual incidence of a hazard). Emergency response also has a specified end event. This is generally defined as the time when the hazard is under control, the people are protected, and recovery efforts can begin.

Table 1
Comparison of Principal Attributes of Projects and Emergency Response.

PROJECTS	EMERGENCY RESPONSE
• Projects have specific goals. If there is no specified purpose, there is no need to start a project.	• Emergency response has specific, recognized goals.
• Projects have specific start and end time frames, they are not continuous.	• Emergency response has a specific starting event and a specific ending event.
• Projects have defined, limited resources.	• Emergency response is constrained by the resources available when an emergency occurs.
• Projects consist of a series of interdependent tasks which must be performed in a certain order.	• Emergency response involves highly interrelated tasks in which effective coordination is critical.
• Projects have specific milestones or time frames when certain objectives must be achieved to ensure that the final goals are met.	• Intervention to provide emergency response assistance must be sensitive to the tempo of the event.

Projects and emergency response are both constrained by limited resources. Project resources include people, things and information. The supply of these resources is limited and rather inflexible to demand. Most projects cannot arbitrarily increase the number of people available if milestones are not being met. The situation in emergency response is analogous. If an event occurs during off-duty hours, the supply of personnel and resources available to assist early response will be severely constrained in most communities. An event occurring during regular business hours will benefit from greater resource availability.

Projects and emergency response both consist of a series of interdependent tasks. Project management techniques break a project down into a set of steps leading from, say, a set of architect's drawings to a completed building. The project schedule is defined by outlining the relationship between project steps, such as the need for the building frame to be erected before electrical wiring begins. Similarly, emergency response tasks form a chain of events leading from, for example, detection of a hazard to protection of populations at risk. The tasks in emergency response are typically linked by the information which must be passed between them.

Projects and emergency response are both carried out in highly time-sensitive environments. Emergency response support must be provided in time to affect the course of events and attendant consequences. The right action taken too late will not only be late but may be totally ineffective in reaching goals. Delay in performing tasks can doom a project to a delayed completion. Delay in performing critical emergency tasks does not just make the response late; it makes it superfluous.

Quantitative project management is based on the attributes of projects. Project management techniques empower managers to:

- Identify the tasks that need to be completed to meet project goals.
- Identify the relationship between tasks. This relationship defines task precedence.
- Determine if the project can be completed in time within the stated constraints of resources and scope of defined work.
- Discretely measure the time necessary for completion of specified milestones based on the duration of activities.
- Determine the cost of the project based on use of projected resources.
- Vary project attributes to determine the resultant effect on cost and schedule.
- Measure planned progress against actual performance and use this information to determine if the project will achieve identified targets.

All these attributes are critical to emergency response. The central paradigm of quantitative project management is the breakdown of goals into discrete tasks and the management of time and cost through planning and tracking. This paradigm is wholly applicable to emergency response, with the additional caveat that emergency response must evaluate plans not against actual performance but expected performance. We cannot wait for an emergency to deduce if emergency plans will work. The evaluation of emergency plans must be based on walkthroughs, exercises, and drills.

RESPONSE PLANNING EVALUATION USING PROJECT MANAGEMENT TECHNIQUES

It is impossible to control what you cannot measure. To control emergency response, it is important to determine when response plans will not achieve their primary goal of saving lives. A plan evaluation must be detailed and quantitative to provide explicit guidance on how much improvement is needed and whether changes being made are leading to improvements in the right direction. Such continuous improvement through measurement and modification is the foundation of the Total Quality Movement (TQM) and Statistical Process Quality Control (SPQC) movements. Both TQM and SPQC have led to substantial gains in the improvement of manufacturing and service processes. The rise of Japan as an industrial competitor has been linked to these techniques. Progressive companies and government agencies in the United States are attempting to integrate TQM and SPQC into their operations. The Malcom Baldridge Quality Award is based on the same notion of process control through measurement and evaluation.

For the Systems Analysis project, IEM has developed techniques to apply detailed measurement to emergency response planning using computerized project management tools. Plans for each CSEPP site were analyzed and converted into an integrated project chart. Principal actions that support saving lives were mapped for all major emergency response elements: Army stockpile installations, EPZ counties, and states. IEM also included in each model the actions presumed to be taken by the responding population.[2] IEM and site personnel worked together to estimate task durations and establish task precedences. Protective action time estimates for the chosen protective action strategy (evacuation or sheltering) were modeled as part of the response model. A clear, quantitative picture of the response system at a site emerges through such response modeling.

This response model was compared to the time expected to be available during response. Using simulation models to map atmospheric dispersion of chemical agent vapors, a time of arrival of the hazard was derived. The response model was compared to the time of arrival of hazard. Clearly, the goal of saving lives is not met if people at risk are not protected when the hazard arrives at their location.

The use of project management techniques addresses the characteristics of emergencies that are too easy to neglect in response planning. Project management tools are designed to highlight the time pressures, task dependencies, and resource constraints that are common to projects and emergency response. Although project management does not concern itself particularly with the problem of uncertainty, a well-defined response schedule does indicate areas where tasks need to be done before concrete information is available.

A Systems Analysis has been performed for six of the eight chemical stockpile sites. These visits have demonstrated the validity and value of this evaluation technique. It has been cited by a number of the sites as providing guidance for plan modifications.

CONCLUSIONS

The response modeling for the six chemical stockpile sites has indicated that this technique is extremely beneficial. Emergency managers' response to the Systems Analysis has been overwhelmingly positive. The technique has a number of clear advantages. Firstly, emergency managers are able to get a clear, coherent picture of the sequence of actions for the complete response system. This leads to a better understanding of the needs and constraints of other jurisdictions and agencies involved in emergency response. Such understanding can form the basis for greater coordination and integration of response. Secondly, it is clear from participant comments that the Systems Analysis allows a distinction between desired efficacy of response and modeled efficacy of response. Many managers stated that tasks needed to be completed within five minutes of the event occurring. The Systems Analysis made apparent that these tasks, as presently constituted, could not be completed in the desired time frame. To meet the desired time frames, the nature of tasks performed, their relationships, and resources may need to change. Thirdly, since the hazard arrival time can be integrated into the model, the hazard and the intended response are both defined in the same terms, in terms of time. Finally and most importantly, the technique provides a clear evaluation of the extent to which emergency response plans can be expected to meet protection goals under different hazard conditions.

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[1]CSEPP Policy Paper No. 1

[2]This element is often neglected in emergency planning. Populations-at-risk are presumed to respond as directed by the emergency managers. However, researchers have repeatedly found in empirical studies that a complex pattern of decision making and action exists at the individual and social levels during emergencies.

THE IMPACT OF AUTOMATION ON THE CHEMICAL STOCKPILE DISPOSAL PROGRAM

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ABSTRACT

Current plans for the disposal of the nation's stockpile of chemical weapons has brought advanced simulation and modeling systems to organizations, a number of which heretofore have had little or no access to automation. The information required by and provided by these technologies has had a dramatic impact on both the personnel involved as well as traditional planning philosophies. This paper discusses this impact and offers insights for simulation application developers on the impact of their work.

1. HISTORICAL BACKGROUND

In compliance with agreements signed by several nations at the Chemical Weapons Convention in January of 1993, the United States is mandated to destroy its current stockpile of chemical agent munitions before the year 2000, with the possibility of a one-time, five-year extension until 2005.* In all, this amounts to some 25,000 tons of chemical agents. Some of these agents are stored in explosive ordinance, some in bulk storage containers

The locations of these stockpiles were chosen for various reasons, not the least of which was their relative remoteness from civilian populations or other large strategic targets as defined in the Cold War years. For several of the stockpile sites, this remains true today. However, protection of the civilian population around these sites is still imperative, which led to the creation of the Chemical Stockpile Emergency Preparedness Program (CSEPP) under the auspices of the US Army and the Federal Emergency Management Agency (FEMA).

The method proposed by the US Army for the disposal of these munitions is through incineration. This activity is currently being conducted on Johnston Atoll in the South Pacific. However, after a risk assessment was conducted, it was decided that on-site disposal of the chemical agent stockpile in the continental United States was safer overall than transport to a single demilitarization facility. Currently, the US Army plans to construct incinerators at eight stockpile sites in the United States.

2. SIMULATIONS FOR CSEPP

To assist emergency personnel plan for emergency response, the US Army has

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* National Research Council, Alternative Technologies for the Destruction of Chemical Agents and Munitions, National Academy Press, 1993, 1.

provided them with some relatively advanced modeling and simulation technologies, along with support for training in the proper use of these technologies. My company, Innovative Emergency Management, Inc., has been tasked to provide this training support.

Two distinct automated systems have been developed under US Army directives for use by military and civilian CSEPP personnel. The first, IBS (Integrated Baseline System), was developed by Pacific Northwest Laboratories (Richland, Washington). It is designed to support CSEPP planning and response for civilian personnel. The second, EMIS (Emergency Management Information System) was designed by Applied Computing Systems (Los Alamos, New Mexico) to support CSEPP planning and response for the Army.

Hazard Simulation: D2PC

Both systems employ the same simulation application for modeling a real or hypothetical release of a chemical agent. This model is known as D2 for the second iteration of a dosage modeling system developed by the Army for battlefield simulations. It has been ported to the PC and now goes by the acronym D2PC.

Evacuation Simulation: IDYNEV

In addition to the D2PC model, the civilian automated system (IBS) includes an evacuation simulation called IDYNEV. This model uses current US Census Bureau data to simulate the migration of populations along evacuation routes created or modified by the end-user. In IBS, the user may choose to synchronize the D2PC simulation with the IDYNEV simulation to obtain a comprehensive view of both human behavior and the potential impact of an accidental release of chemical agent on the human population.

Details of the Simulations

The D2PC model requires various types of input from the user, primarily information about the nature of the chemical agent release and current or hypothetical meteorological conditions that will affect how the agent is dispersed in the atmosphere. The user must know, for example, the type of chemical agent released (since physical properties bear upon the behavior of the agent in air), the nature of the event (explosive, spill, etc.), the amount of agent involved, and the type of munitions. Each of these inputs may require additional data.

The meteorological data required may be real-time (for sites which have meteorological recording stations) or hypothetical. Obvious required data include wind direction and speed, temperature, and the Pasquill stability class which may be calculated by the model based upon certain defaults for the site in question. Other meteorological data, such as the height of the mixing layer, and the Frost slope profile, may be entered by the user or taken as default for a particular site and season.

Together, the event data and the meteorological data are processed by the D2PC simulation to generate both textual and graphical output. In the case of graphical data, these are converted into a depiction of the dispersion of the agent over space. This depiction includes "dosage contours" established by the model and actual transit time data generated by another function PARDOS (PARtial DOSage) which shows where the agent cloud will be at what time.

A sample screen showing a hypothetical release of nerve agent is shown in Figure 1.

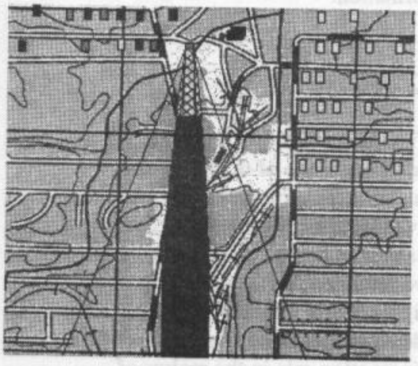

Figure 1: Hypothetical release of chemical agent as depicted by D2PC model and PARDOS

The IDYNEV simulation requires similar data from the user. First, users must develop an evacuation network for each area at risk from a potential chemical agent event. This requires them to create "centroids" which indicate where the population will enter the network, "links" which describe road characteristics such as the number of lanes, where turns may be made, and so forth, and "nodes" which represent intersections or changes in road type. Furthermore, additional data regarding people and their behavior is required. These data include population type (daytime/nighttime), and persons per vehicle, and the loading rate for the evacuation model.

The IDYNEV simulation steps the model through time at increments which may be set by the user. At each step, the user may query a point, node, or link, to determine such things as the current average speed on a link, the number of people who have passed through a node, the percentage of the total area population that has exited the network, and so forth. A sample of the IDYNEV output is shown in Figure 2.

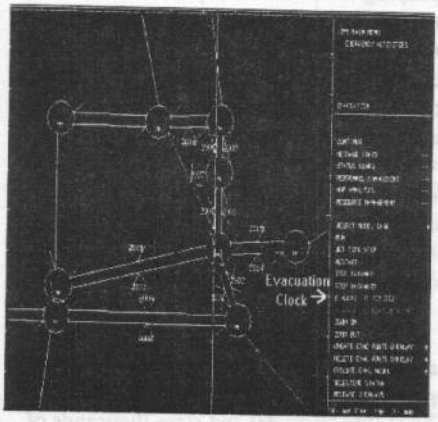

Figure 2: Output from the IDYNEV evacuation model

3. IMPACT

The impact of this technology on the organizations that are now using it is enormous. For many of the communities that IEM is involved with in training, this represents quite literally the first automation they have used outside of a word processor. It is, in the best of cases, the first automation they have used that provides simulation technologies.

Access to these technologies carries with it what I, as a trainer, would call a "paradigm shift" in the minds of the planners and responders I have trained and talked with. Wholly new methods of data gathering, new insights into what the simulation technologies provide, and new guidelines for coordinating this information across various jurisdictions must be considered. Simply put, these simulation technologies promise a wealth of information and guidance must now be considered on how this information should or must be handled. Personnel who may have had no greater responsibility than notifying the local fire department of a hazardous material spill are now expected to provide decision-makers with detailed and accurate information on the behavior of a complex chemical compound under various meteorological conditions. Planners who were weaned on the philosophies of the Cold War era face similar challenges from simulation technology. What happens to plans forged with pen and paper in the face of simulation technologies?

Accommodating these new technologies has also resulted in a phenomenal demand upon personnel at most of the CSEPP sites. The ability to model and store thousands of simulated agent releases and tens of evacuation simulations requires considerable dedication and time on the part of CSEPP personnel.

Political Issues

The types of data required by the D2PC and IDYNEV models also broaches the issue of protocol and policy regarding he exchange of information between military and civilian agencies. For example, the D2PC model requires information regarding the nature of a chemical event that military coordinators simply may not know in the short time-frames required to use the model in the first minutes after an event.

Interpreting the output for the simulation is another issue. The D2PC model is capable of generating contours which indicate various statistical probabilities regarding the effects of exposure to a chemical agent. This is usually displayed as the "No Effects," "No Deaths," and "1% Lethality" contours. Currently policy requires that planners use the lowest of "No Effects" contour. This poses a new dilemma for planners and responders in regard to how best to use this information.

4. CONCLUSION

The point of this brief paper has been to touch upon some of the issues that simulation technologies raise when they are moved from the laboratory to the real world. It cannot be denied that such technologies have provided and will continue to provide insights across virtually all scientific endeavors. Certainly simulations will play an increasing role in the realms of environmental research and hazardous materials handling.

In short, the effect of simulation technologies has been overwhelming in some instances in the CSEPP program. Where before there seemed clear-cut answers to the dilemmas of planning for emergencies, simulation technologies in fact blur these assumptions and force emergency planners to face the question: now that we can model acceptable impact, what impact are we willing to accept?

DECISION SUPPORT SYSTEMS

A Decision Support System for Evaluation and Remediation of Contaminated Sites

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Abstract

A computer aided system is presented which should be an effective support for the government offices which are responsible for the evaluation of contaminated sites and the decision with regard to the kind of remediation. This system consists of two main parts. These are the knowledge based program XUMA and a decision support system.

XUMA includes a knowledge base with the principal methods for handling contaminated sites. The main features belonging to XUMA are:

- Evaluation of contaminated sites
- Creation of analysis plans
- Assessment of contaminated sites
- Knowledge acquisition tool
- Explanation Facility

The decision support system which bases on the decision analysis theory of vonNeumann-Morgenstern with multiple value extensions from Keeny-Raiffa is to support the responsible authorities in order to find out the best kind of remediation from a given set of alternatives.

Introduction

In the last years contaminated sites have become a relevant problem in the Federal Republic of Germany because there exist a large number of these sites. About 10% of these sites have to be remediated. That's why in Germany more intensive efforts are undertaken in order to start necessary remediations. Basic initial conditions for an effective execution of these works are on the on side a systematically registration of these sites and on the other side the creation of an uniform possibility of evaluation in connection with the assessment of environmental hazards.

Beside the 18.000 communal and the 27.000 private sites may be contaminated the responsible governmental offices of the State of Saxony have additional problems during remediation of sites because radioactive components are in the sites of the former Soviet-German Corporation WISMUT which has been an uranium mining corporation.

The Structure of the Environmental IT-System in Saxony

In order to solve the problems regarding the background described above the responsible institutions of the State of Saxony are going to build up a registration and evaluation system for sites may be contaminated.

Figure 1 shows the structure of this registration and evaluation system. The lines between the objects only represent the data flow. On-line data connections don't exist. Therefore the direction of data transfer is defined in the following manner.

The data acquisition takes place at the engineering offices. In order to ensure data consistency and data completeness the engineering offices use an interface program which can be generated automatically from the knowledge base of the expert system XUMA. This interface program was developed by the Research Centre Rossendorf Inc. (FZR - Forschungszentrum Rossendorf) together with the Technical University of Dresden.

After that the data have to be transferred to the office which is responsible for the rural district (LRA - Landratsamt). Each LRA of a governmental district on the one side stores the data and of the other side transfers the data to the responsible governmental office (StUFA - Staatliches Umweltfachamt). Beside storing their own data all StUFAs transfer the data to the Institute of Environmental Protection of the State of Saxony (LfUG - Landesamt für Umweltgestaltung und Geologie). At LfUG the complete data of the State of Saxony are stored. In order to handle these data different programs will be connected with this central data base. Some of the main functions these programs have to realise are shown in figure 2. The upper part of this figure represents the site-evaluation system which is partly implemented in XUMA and the lower one describes the decision support for remedial actions.

The Evaluation Method

The evaluation method used for contaminated sites in the state of Saxony bases on the method which was developed at the State Institute for Environmental Protection of Baden-Württemberg (Landesanstalt für Umweltschutz Baden-Württemberg). The goal of this method is to determine priorities with respect to the environmental hazard and to the further investigations or a possible remediation of the site. In order to evaluate, the site has to be separated into four different media to be protected (ground water, surface water, soil and air). For each of these media the following five steps have to be carried out. Each of these steps contains the calculation of hazard-increasing or -decreasing factors relative to a defined comparative site.

- r0 - risk value of the site (hazard of substances)
- m1 - transport of substances out of the site
- m2 - transport of substances into the media to be protected
- m3 - transport and effects of substances in the media to be protected
- m4 - the significance of the media to be protected concerning the human

These five steps result into a numerical risk value describing the environmental hazard of the site. In dependence on the level of evidence this risk value allows to derive priorities with respect to further investigations and the environmental hazard of the site. The levels of evidence are defined through the kind of investigation. There exist four levels of evidence:

- BN1 - historical investigation is finished (limited informations with assumptions concerning the substances and the geological situation but without any chemical and physical analyses)
- BN2 - oriented investigation is finished (more detailed informations with a limited set of samples and chemical or/and physical analyses)
- BN3 - detailed investigation is finished (detailed informations concerning the substances, the transport of substances etc.)

BN4 - investigation for remediation is finished

In dependence on the described evaluation level and the risk value the following activities are derived:

A - elimination (registration of site with no further investigations or inspections)
B - deposit with the demand for an inspection after a certain time
C - deposit with the demand for continuous technical control measures
D - the demand for checking possibilities in order to reduce the hazard of the site (containment or/and remedial actions)
E - further investigations (not enough informations for decision)

The background for this step by step investigation method is that the costs for investigations increase rapidly from one level of evidence to the next one. With the help of this method many costs can be saved if actions A...C are derived at a lower level of evidence. The flow chart of the described evaluation method is shown in figure 3.

<u>The Knowledge Based System XUMA</u>

Regarding this background the FZR together with the Society for Nuclear Technique and Analysis Rossendorf (VKTA - Verein für Kernverfahrenstechnik und Analytik Rossendorf) apply the computer program system XUMA as one component of the central program pool.

XUMA (German synonym for expert system on environmental hazards of contaminated sites) is a joint project of the Institute for Applied Information Science (Institut für Angewandte Informatik) of the Karlsruhe Nuclear Research Centre (Kernforschungszentrum Karlsruhe) and the State Institute for Environmental Protection of Baden-Württemberg (Landesanstalt für Umweltschutz Baden-Württemberg).

XUMA is a knowledge based computer system, which shell support the staff of the responsible government offices at the uniform evaluation of the hazard potential, the preparation of analysis plan and the assessment of contaminated sites and mines. The system is to relieve the staff in their routine work, makes available the specialists knowledge for them and allows to take into account the most new findings with the help of a knowledge acquisition component.

XUMA runs under the operating system UNIX® on a SPARC workstation. It communicates with a relational database (oracle®) in which the site-specific and the knowledge base data (substances, branches, etc.) are stored. XUMA is designed to the client-server principle. The server is written in Lisp and ART®, a hybrid expert system development environment. The user communicates with XUMA through the client - a Graphical User Interface (GUI), managed by an the User Interface Management System Open-UI®.

The functions of XUMA principally consists of the following five components.

1. Evaluation

The evaluation method used in XUMA corresponds with the method described above.

Functions:
- systematically registration of waste suspected sites and their technical data
- objectivity during site evaluation with the help of a determined comparative risk value
- derivation of a need of action
- estimation of efficiency with respect to activities in order to decrease environmental hazard

Method:
- comparative evaluation of sites may be contaminated
- separate observation of the media to be protected (ground water, surface water, soil, air)
- step by step evaluation of substantial hazard, transport and effects of pollutants and significance of the media to be protected
- evaluation process in the four levels of evidence

The next two components have a great significance at the higher levels of evidence. They evaluate the input data for the evaluation component at these levels.

2. Preparation of analysis plan and analyses acquisition

Functions:
- systematically registration of site-specific samples and analyses data
- derivation of an analysis plan for chemical and physical investigation of the specific site or a typical industrial branch

Method:
- supporting the selection of relevant analytical parameters by substantial or/and branch-specific hints
- three different possibilities of access for the derivation of an analysis plan
  - branch access (use of a branch tree which is implemented in the knowledge base)
  - substantial access (use of knowledge about site-specific waste)
  - standard access (waste with an unknown hazard potential)
- possibility of different detailed substantial investigations corresponding to the level of evidence
- possibility of different detailed analyses of samples corresponding to a eligible investigation level

3. Assessment

Functions:
- assessment of a specific site or a part of the site concerning to its samples, analysis quality and analyses results

Method:
- possibility to choose between three alternatives
  - assessment of an analysis
  - assessment of a complete sample
  - assessment of whole site or a part of it
- kinds of assessment results:
  - quality of samples and/or analyses and their safety (comparison between analysis plan and analyses really carried out)
  - quality classes (classification of the measured values with the help of reference value tables)
  - statements about substances occurred in the site
  - derived assessment statements
  - statistics

In order to use this expert system effectively and to get an acceptance from the governmental offices, the two additional components are implemented. These are the explanation facility and the knowledge acquisition facility.

4. Explanation

The explanation facility enables the reconstruction and verification of the results. It shall help the user to check the plausibility of solution and to reconstruct the derivation path. Furthermore, it shall enable the expert to trace back the results to the basic knowledge and to prove the correctness of the solution.

Functions:

- explanation of derived assessment statements in natural language

Method:

- mouse-sensitive explanation of statements concerning the assessment in two justification levels
- the local justification describes:
  - the fact to be explained
  - the name of the rule, which has derived this fact
  - the rule content in natural language
  - the facts which have fulfilled the conditions of the rule
- the global justification describes:
  - the complete derivation tree of a statement
  - the possibility of rule-editing

5. Knowledge Acquisition

With the help of the direct knowledge acquisition facility the expert user is able to modify and complete the knowledge base. That means, the facility allows the manipulation (addition, modification, deletion) of objects and rules without any experience in programming.

Functions:

- changing or completing the knowledge base with respect to the following components:
  - substantial data
  - analysis parameter
  - branches of industry
  - reference value tables
  - rules with regard to reference value tables
  - rules with regard to analysis parameters
  - evaluation features

Method:

- menu-controlled choice of the part of the knowledge base to be edited
- support of rule editing by a rule editor which represents the eligible rule components in a natural language manner

Beside the Saxony-specific modification of the evaluation knowledge base FZR and VKTA are going to implement components, in order to get a suitable knowledge based system also for radioactive contaminated sites. The implementation of this "radioactive tree" requires the insertion of complex computer simulated calculation modules, because the distribution of radioactive substances in the environment, the radioactive decay and the transfer to human plays an exponent rule. This includes

- distribution in the air, in the surface water and in the ground water
- bio-transfer chain earth - plant - animal - human
- the radioactive decay during distribution and bio-transfer
- the different hazard of radioactive substances for the human

The relational data base ORACLE is to use as the connection between the expert system and the calculation modules. With these implementations the knowledge based system has the in picture 4 showed structure.

<u>Decision Support for Remedial Actions</u>

When the need for remedial actions at the contaminated site has been determined, the responsible authorities are faced with the problem of designing and comparing feasible remedial alternatives. As the investigation process at the site gives in general a good overview of the type of contamination and the surrounding environment, several plausible remedial scenarios can be constructed easily. Comparing these alternatives and taking a decision for one of them in a rational and defensible way is hard to achieve. This task is furthermore complicated by conflicting arguments for the alternatives and uncertainty about the actual outcomes.

This is a typical situation for the use of decision analysis. To assist the responsible authorities in taking their decision, we apply methods based on the theory of vonNeumann-Morgenstern [vonNeumann-47] with multiple value extensions from Keeney-Raiffa [Keeney-76]. If the decision maker is willing to act according to the axioms defined in this theory, the existence of a real-valued utility function u is assured, that accurately reflects the preferences of the decision maker over the state of possible outcomes $\boldsymbol{X}$. This function can be used to evaluate the different alternatives i taking the uncertainty (represented by a probability function p_i over $\boldsymbol{X}$) and the multiple objectives explicitly into account. This is done by calculating the subjective expected utility SEU_i for every alternative.

$$SEU_i = \int_x dx\, u(x)\, p_i(x)$$

Additionally further investigation of the decision situation can be performed via sensitivity analysis and by calculating the value of additional information.

The application of the theory described above consists of the following three succeeding steps.

1. Definition of the utility function u

The definition of the utility function starts with the construction of an appropriate outcome space. The restrictions the outcome space has to comply with can be found in [von-Winterfeldt-86, pp. 36]. The application of the theory currently under way was complicated by the existence of several, decision relevant agents with different opinions about the important values in the outcome space. As an agreement about the outcome space to use was nevertheless achieved, step 2. has already started. For the codification of the preference structure into a unifying utility function computational aids are required (see step 3.).

2. Assessment of the probability distributions p

The assessment of the probability distributions for the alternatives is a complex problem. The input data consist primarily of measurements, statistical data and subjective estimations. These data are connected by functional dependencies, complex simulation programs and approximations to the decision relevant outcome space. Additionally possible events during the remediation process must be taken into account and the consequences of them estimated. Especially these events lead to probabilistic dependencies between different values of the outcome space.

To represent the various data and relationships graphically an editor for functional networks was programmed. Because the same editor can also be used to define the utility function, a unifying environment is available.

3. Calculation of SEU_i and advanced investigations

At this point, a functional network representation of the p-distributions and the utility function has been constructed. To calculate the SEU for the alternatives it is necessary to compute the p-distribution of the utility function u. Unfortunately it is not computationally feasible to calculate the distribution directly because of the various probabilistic dependencies mentioned above. Therefore we had to use Monte-Carlo techniques [Morgan-90]. A big advantage of these techniques is the easy implementation of a sensitivity analysis. If the program package is finished, a unifying environment for the definition of utility functions, for calculating p-distributions, for evaluating alternatives with the SEU and for advanced investigation of the decision situation will be available.

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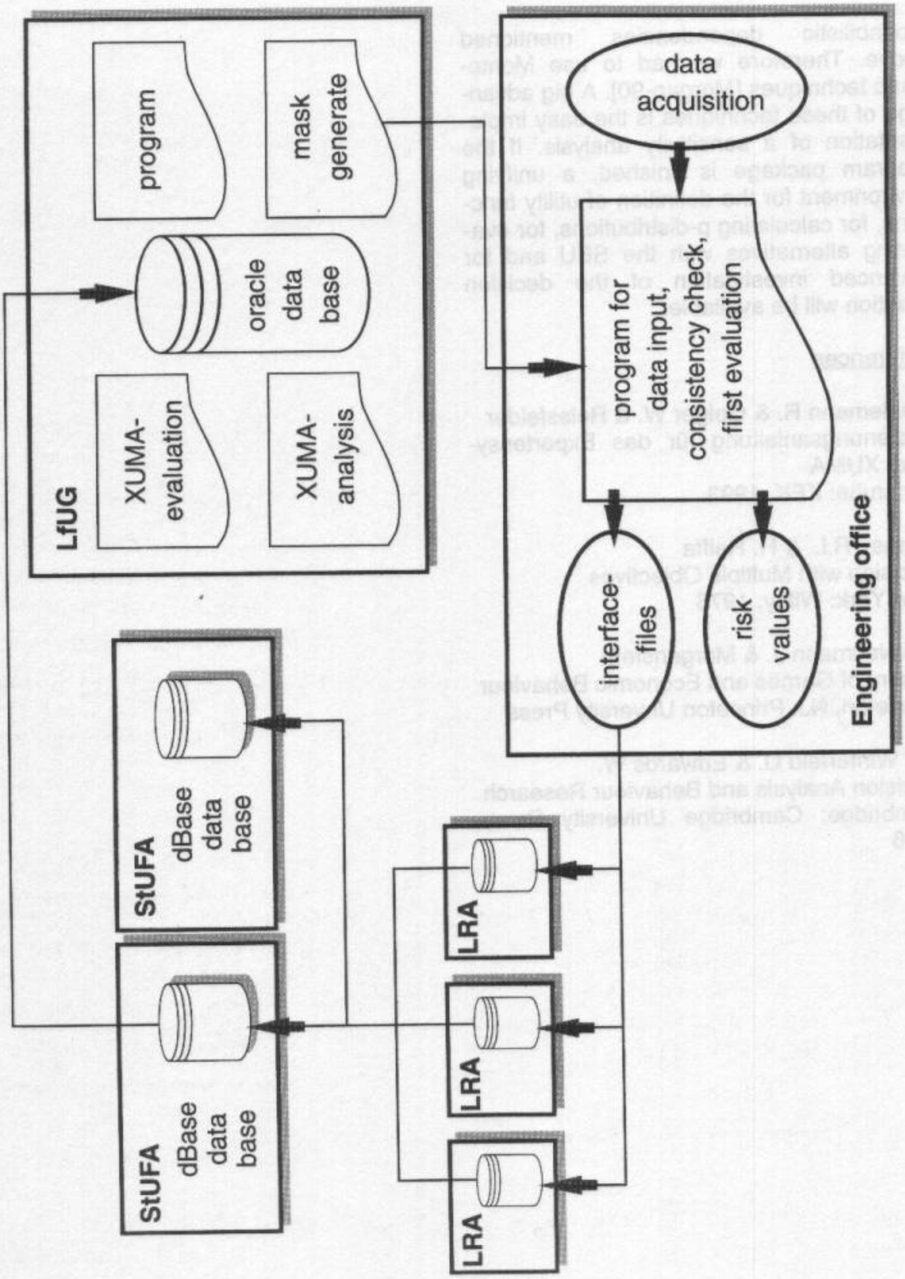

Figure 1 The local structure of the registration and evaluation system in the State of Saxony

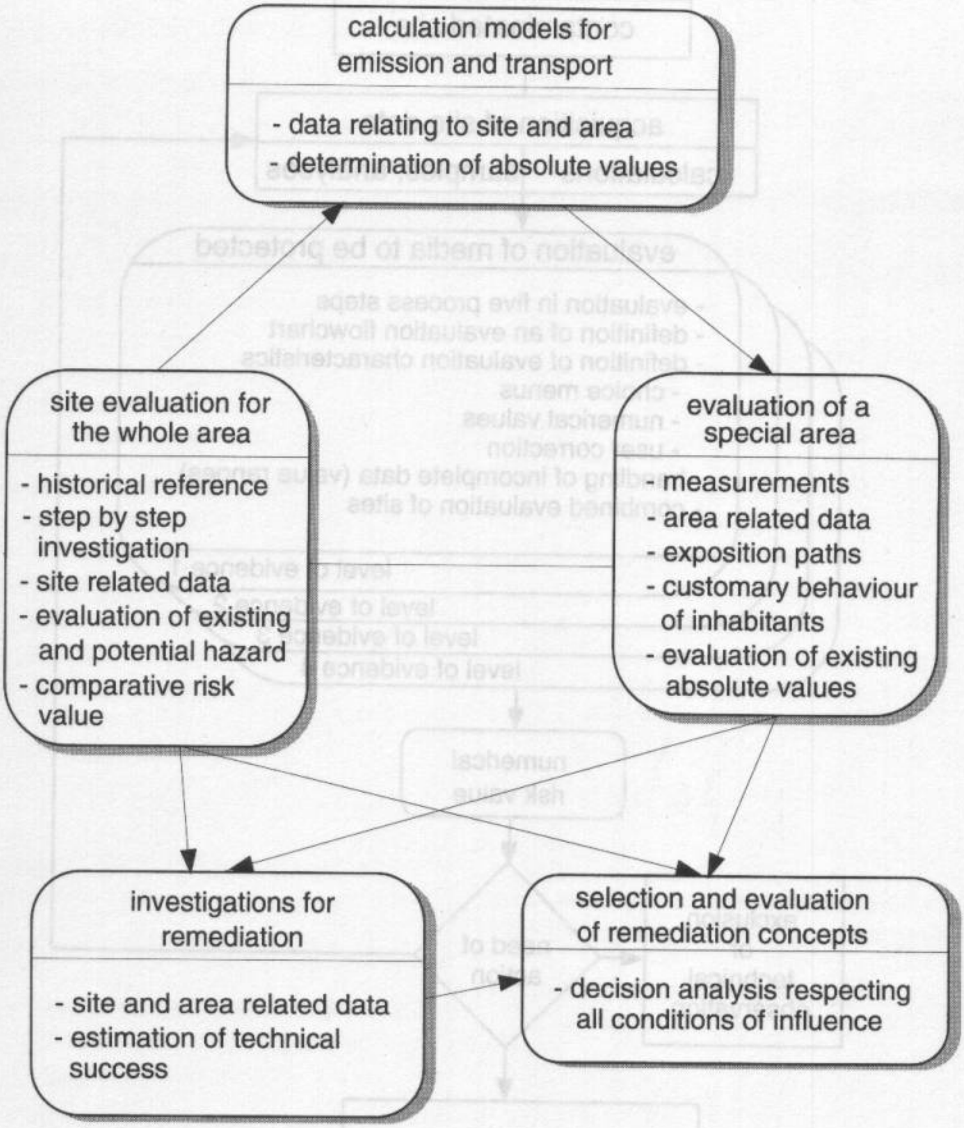

Figure 2 The main components of a site evaluation and remediation system

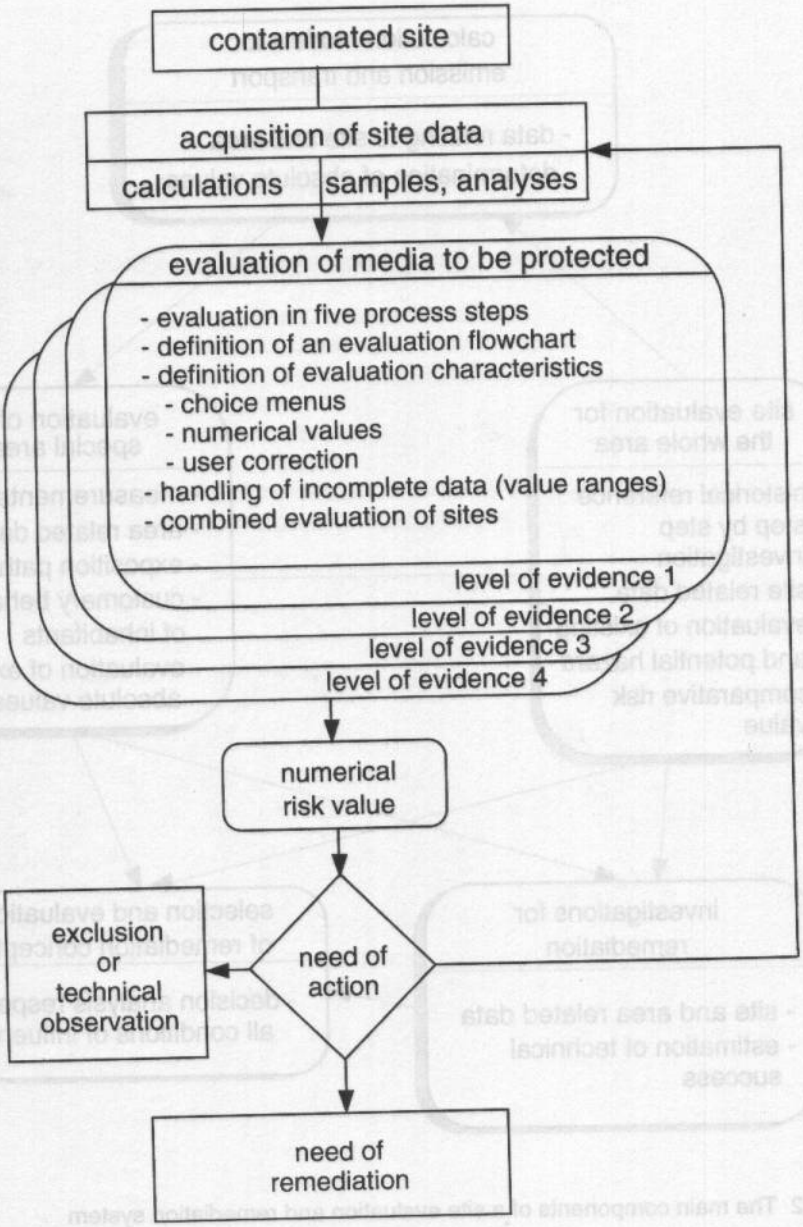

Figure 3 The flowchart of site evaluation

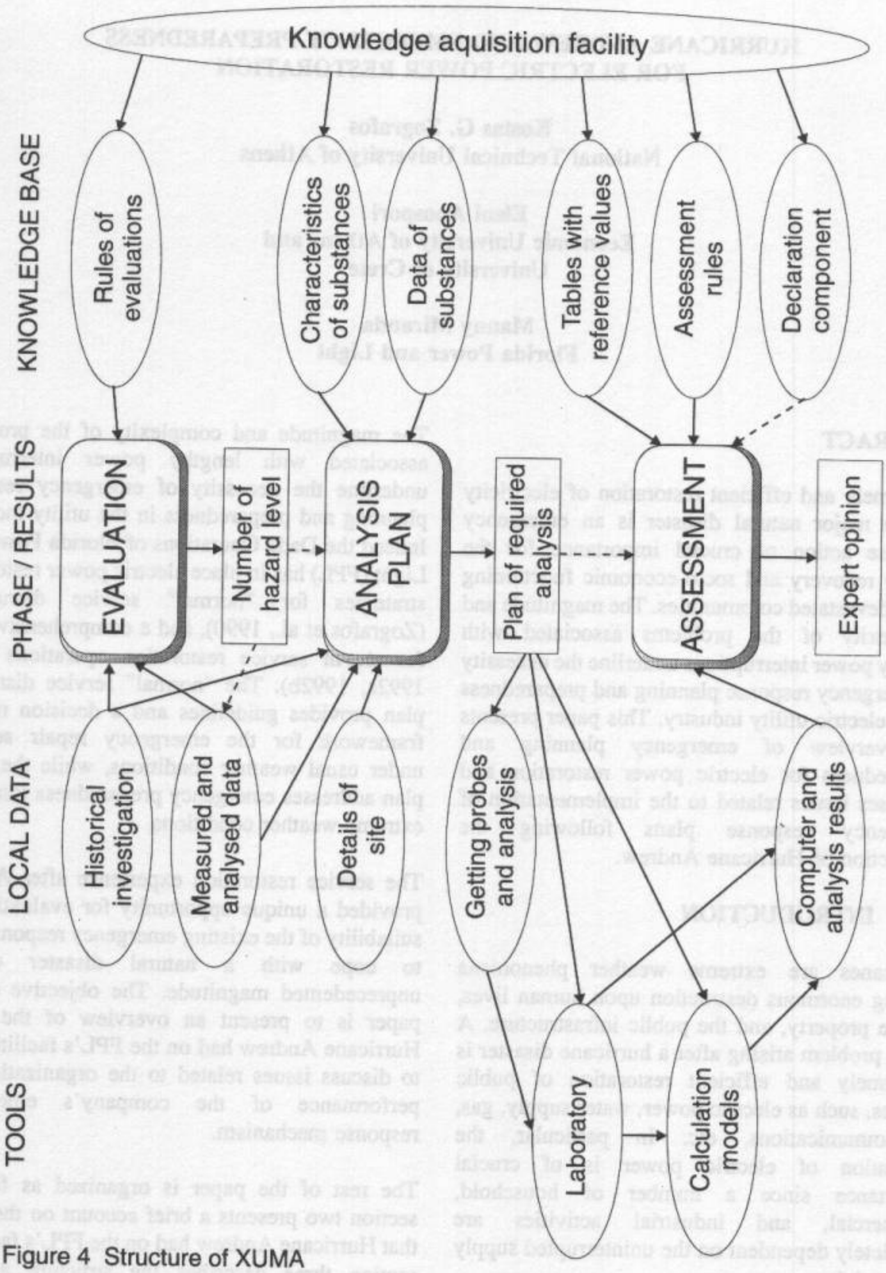

Figure 4 Structure of XUMA

HURRICANE ANDREW AND EMERGENCY PREPAREDNESS FOR ELECTRIC POWER RESTORATION

Kostas G. Zografos
National Technical University of Athens

Eleni Apospori
Economic University of Athens and
University of Crete

Manny Miranda
Florida Power and Light

ABSTRACT

The timely and efficient restoration of electricity after a major natural disaster is an emergency response action of crucial importance for the speedy recovery and socio-economic functioning of the devastated communities. The magnitude and complexity of the problems associated with lengthy power interruptions underline the necessity of emergency response planning and preparedness in the electric utility industry. This paper presents an overview of emergency planning and preparedness for electric power restoration and discusses issues related to the implementation of emergency response plans following the destruction of Hurricane Andrew.

1. INTRODUCTION

Hurricanes are extreme weather phenomena causing enormous destruction upon human lives, private property, and the public infrastructure. A major problem arising after a hurricane disaster is the timely and efficient restoration of public utilities, such as electric power, water supply, gas, telecommunications, etc. In particular, the restoration of electric power is of crucial importance since a number of household, commercial, and industrial activities are completely dependent on the uninterrupted supply of electricity.

The magnitude and complexity of the problems associated with lengthy power interruptions underline the necessity of emergency response planning and preparedness in the utility industry. Indeed the Dade Operations of Florida Power and Light (FPL) has in place electric power restoration strategies for "normal" service disruptions (Zografos et al., 1990), and a comprehensive plan for **storm** service restoration operations (FPL, 1992a, 1992b). The "normal" service disruption plan provides guidelines and a decision making framework for the emergency repair services under usual weather conditions, while the storm plan addresses emergency preparedness issues for extreme weather conditions.

The service restoration experience after Andrew provided a unique opportunity for evaluating the suitability of the existing emergency response plan to cope with a natural disaster of an unprecedented magnitude. The objective of this paper is to present an overview of the effect Hurricane Andrew had on the FPL's facilities and to discuss issues related to the organization and performance of the company's emergency response mechanism.

The rest of the paper is organized as follows: section two presents a brief account on the effect that Hurricane Andrew had on the FPL's facilities; section three describes the structure and the philosophy of the pre-storm service restoration plan; section four presents the new organizational structure of the company's service restoration plan, and section five summarizes the results of this research.

2. HURRICANE ANDREW AND ITS EFFECT ON ELECTRIC POWER DISTRIBUTION AND TRANSMISSION NETWORK

Hurricane Andrew's eye made landfall near Florida City, approximately 25 miles south of downtown Miami at 4:52 a.m. on Monday August 24, 1992. Andrew's sustained wind speed was reported to be approximately 145 mph (65m/sec), with the highest storm surge reported in Key Biscayne at 16.9 feet. Hurricane Andrew moved through South Florida in a westerly direction with a speed of about 16 mph. According to the Saffir-Simpson Scale Hurricane Andrew was classified as a category 4 hurricane.

The destructive forces of Hurricane Andrew had a devastating effect on the power transmission and distribution facilities in four of the five FPL operational territories. As a result of Hurricane Andrew 1.4 million FPL customers left without power immediately after the storm. Approximately half (690,000) of the affected customers were located within the service boundaries of the Dade Operations (Dade County), while the balance of the affected customers was distributed among the Broward (470,000 customers), Palm Beach (140,000 customers), Collier (61,300 customers), and Lee (16,600 customers) counties.

The damage inflicted on the FPL's power transmission and distribution network by Hurricane Andrew is exemplified by the enormous quantities of materials and labor required for the restoration/rebuilding of the power network. The results of the damage assessment performed by FPL personnel suggest that 2555 miles of overhead conductor were destroyed, almost 13,000 transformers were damaged, and 20,058 poles were installed. Table 1 summarizes the materials and manpower requirements for Hurricane Andrew.

Analysis of the spatial distribution of the damaged facilities suggests that the destruction caused by Andrew was unevenly distributed among the various service centers of Dade County. Areas located at the northern part of the county, outside the eye of the hurricane, sustained repairable damage of their power distribution system. However, areas located in the southern part of the county were destroyed to the point that "rebuilding" rather than restoration of the power system was necessary.

The substantial differences observed on the level of destruction between the northern and southern part of Dade County were rightly reflected on the progress of the service restoration process between the two parts of the County. Thus, the service restoration mechanism of the northern part of the county was able to restore services, according to the pre-determined storm plan, in a fast manner. As it can be seen in figure 1 the service restoration process for the northern part of the county was concluded within 14 days, while the service restoration process for the southern part of the county required almost one month.

Major logistical problems were created due to the devastation of the community and the inability of local vendors to supply the needed resources for supporting the restoration effort. Logistical support statistics for the electric power restoration effort after Hurricane Andrew are presented in table 2. Furthermore, the dismantling of the traffic signal network of Dade County by the hurricane and the blockage of the roadway with debris made the logistical support of the field personnel extremely difficult.

3. THE PRE-STORM SERVICE RESTORATION PLAN

Dade Operations of FPL had in place a comprehensive storm service restoration plan. This plan was substantially improved and updated after FPL personnel visited the South Carolina area following the destruction of Hurricane Hugo. The 1992 Storm Service Restoration Plan (FPL, 1992a; 1992b) had incorporated a number of "lessons learned" from Hurricane Hugo. From an organizational point of view the pre-storm plan was based on a Modular Management Concept which minimizes confusion and wasted time (FPL, 1992a).

The organizational chart of the pre-storm service restoration program involves an operations area headquarters manager who oversees and coordinates the storm-restoration operations. Reporting to the **Area Storm Manager** are coordinators of various functions such as Employee Services, Safety, Switching, Industrial Relations, External Affairs, Governmental Affairs, Media, Customer Service, Commercial Residential Operations, Distribution Restoration, Transmission Substation Restoration, Claims, Storm Accounting, Environment, and Inventory Services/Fuel Staging Areas. Because of the expected increase in workload, the geographical area of each service center was further subdivided into smaller operating areas, called storm centers. **Storm centers** include one or more substations with their respective distribution feeders (FPL 1992a).

From an operational point of view the storm-plan had well established priorities for restoring services. According to the plan the service restoration prioritization scheme was based on a list of essential customers. This list included hospitals, Public Service organizations, Communications organizations, Sewage and water supply pumping stations, and transportation facilities. Power transmission and distribution facilities providing services to the essential customers were identified by the respective storm centers and the repair process was implemented in a hierarchical order following the sequence feeders, laterals, individual services.

Although the pre-storm service restoration plan provided an organizational infrastructure and procedural guidelines for restoring power in a fast and efficient manner, the magnitude of the devastation caused by Hurricane Andrew created unforeseen needs and therefore it had to be modified and enhanced accordingly. The following section presents a brief description of the new organizational structure of the storm emergency plan.

4. THE NEW STORM SERVICE RESTORATION PLAN

An important aspect of the post-hurricane service restoration operations was the establishment and operation of staging areas. The use of staging areas proved to be an extremely beneficial strategy especially in the hardest hit southern portion of Dade County where the magnitude of the devastation called for rebuilding rather than repairing the damaged power transmission and distribution system. The pre-storm plan included the concept of the staging areas as physical sites that would accommodate the storage of the additional equipment needed for the restoration process. The staging areas did not constitute separate organizational/operational units and, therefore, there were not part of the prestorm organizational chart. Early in the restoration process it was understood that the concept and mission of the staging areas had to be modified. Thus, the staging areas evolved from "over-flow parking lots" to autonomous storm centers encompassing all the essential storm restoration functions. Materials, equipment, and supporting facilities for the crews and their equipment became available at the sites of the staging areas. In addition an administrative structure was developed in order to support the operation of the staging areas.

The results of the operation of the "upgraded" staging areas were tremendous. **The time wasted by the crews to travel to and from their work sites to the places where materials and support functions were available was dramatically reduced. As a result the crews were spending more time productively repairing and rebuilding the power transmission and distribution network.** The provision of essential service and support facilities at the staging areas, such as meals, ice/water, sanitation, communication, check-cashing,etc., improved substantially the working conditions of the crews which otherwise had to work under adverse conditions. The provision of these facilities helped to keep the morale of the working crews high with beneficial effects on their performance and productivity.

From an administrative point of view the establishment of the "upgraded" staging areas was also beneficial since the completed work was more efficiently monitored and reported. **Without doubt the use of the staging areas was instrumental in achieving the target dates in restoring services after the hurricane.** The positive experience derived by the establishment and operation of the "upgraded" staging areas was considered of extreme value and, therefore, the new storm organization includes the staging areas as autonomous and self-standing organizational/operational units.

5. CONCLUDING REMARKS

Hurricane Andrew had a devastated effect on the FPL power transmission and distribution facilities. However, the spatial distribution of the destruction was not uniform. Two drastically different levels of destruction were identified during the post-hurricane damage assessment between the Southern and Northern part of Dade County. In particular, it was found that the power transmission and distribution network located at the Southern part of Dade County was severely damaged and rebuilding of the system was necessary. However, the majority of the facilities located at the Northern Part of the County sustained repairable damage.

The post-hurricane restoration effort was based on a storm-plan that was rehearsed during the dry run that took place during May 1992. Further, it was found that the key personnel of the service restoration mechanism had a very good knowledge of the storm plan and its implementation procedures.

The plan was judged to be adequate in terms of its strategic aspects and without doubt provided the necessary decision making support for the post-hurricane restoration operations. The plan was making explicit reference to priorities and responsibilities and it was covering all of the strategic functions for the efficient restoration of services. The timely and efficient deployment of the field units made essential the development of staging areas. The staging area concept increased immeasurably the speed and efficiency of the restoration process.

The evaluation of the post-hurricane service restoration operations has shown that FPL was successful in providing timely service restoration to its customers. This success is mainly attributed to the existence of an adequate storm-plan, the capabilities, skills, the team spirit, the motivation, and the high-professionalism of the personnel participated in the service restoration effort. The tremendous experience accumulated by the service restoration mechanism during the post-hurricane period constitutes a valuable resource for the future enhancement and improvement of the existing storm-plan and storm-training procedures. The continuous monitoring, evaluation, and improvement of the storm plan and the enhancement and development of the storm training program constitute the main ingredients of a successful storm preparedness strategy.

ACKNOWLEDGEMENTS

The authors wish to acknowledge with thanks, the assistance of Mrs. Laura Kaplan and Mr. John Haupt.

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Table 1: Hurricane Andrew: Service Restoration Statistics

CUSTOMERS WITHOUT POWER	1.4	MILLION
OVERHEAD CONDUCTOR	2,570*	MILES
SERVICE CABLE	733	MILES
POLES	21,100	
TRANSFORMERS		
* AERIAL	11,415	
* PAD MOUNTED	730	
STREET LIGHTS		
* HEADS	9,585	
* LAMPS	26,158	
* POLES	285	
* PHOTO CELLS	25,417	

[Source: FPL] (*) Distribution only.

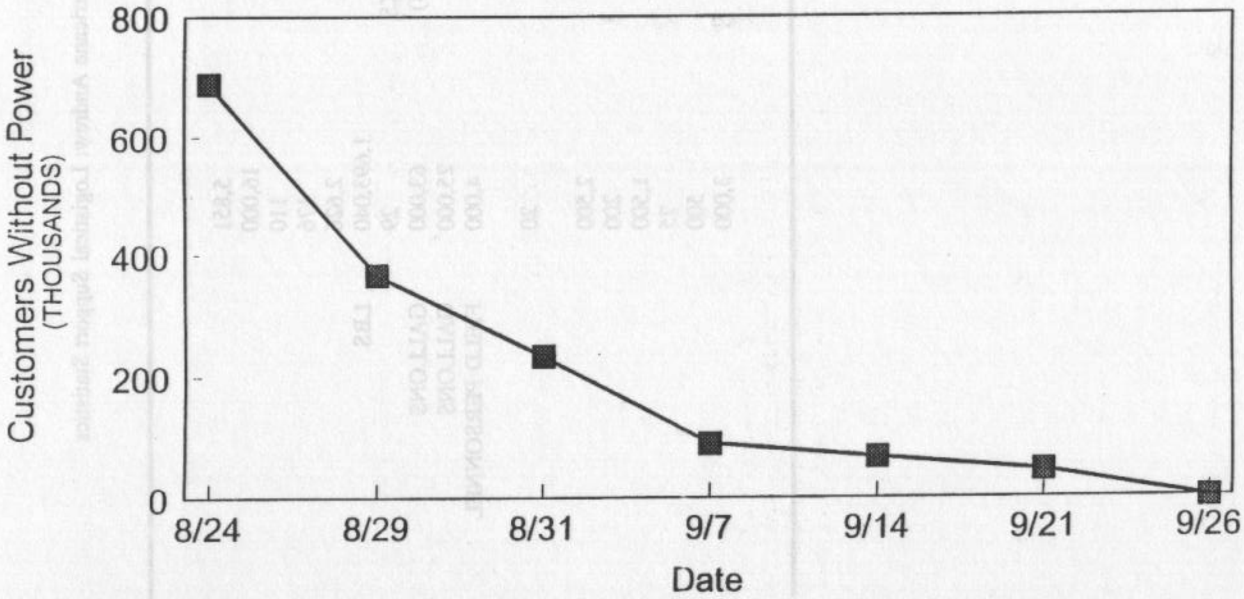
Table 2: Hurricane Andrew: Logistical Support Statistics

PERSONNEL	5,851	
MEALS/DAY	16,000	
BUSES/DAY	110	
SECURITY	176	
HOTEL ROOMS/DAY	2,626	
ICE (FIRST 3 WEEKS)	1,693,040	LBS
REFRIGERATION TRUCKS	29	
WATER (FIRST 3 WEEKS)	63,000	GALLONS
FUEL/DAY	25,000	GALLONS
LAUNDRY/DAY	4,000	FIELD PERSONNEL
NUMBER OF NURSES	20	
CASES TREATED		
BLOOD PRESSURE	2,500	
TETANUS BOOSTER	200	
CUT/ABRASION	1,500	
BURNS	75	
RUSHES	500	
MISCELLANEOUS	3,000	

[Source: FPL]

Dade County Hurricane Andrew

Figure 1: Progress of the Service Restoration Process



SOFTWARE DIRECTORY

The following pages provide some basic information supplied by the authors. TIEMES and the cooperating organizations have not verified this information and are not endorsing these products; this information is relayed to the reader as a courtesy to the authors.

ITEM NAME: Emergency Information System for Windows (EIS/Win)

BRIEF DESCRIPTION:

The Emergency Information System for Windows (EIS/Win) runs on IBM PC's or compatibles and integrates maps, databases, air dispersion models, sensors, imaging and real-time data communications.

CONTACT: James W. Morentz, Ph.D., EIS International

Street address: 1401 Rockville Pike, Suite # 500

City: Rockville

State: Maryland

Postal code: 20852

Country: USA

Telephone: (301) 424-2803

COMPUTER: IBM PC's and compatibles.

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

Microsoft Windows.

PERIPHERALS REQUIRED:

COST: Varies.

ITEM NAME: ETH-RISK

BRIEF DESCRIPTION:

Is designed as modular, expandable, articulated GIS-oriented platform, for risk and accident consequence assessment/emergency planning for nuclear power plants.

CONTACT: Adrian Gheorge, Polyproject "Risk and Safety"

Street address: ETH-Zentrum

City: 8092-Zurich

State:

Postal code:

Country: SWITZERLAND

Telephone: 004-1-1-632-5938

COMPUTER: IBM-PC

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

Microsoft MS-DOS

PERIPHERALS REQUIRED:

COST: $1,000 US

ITEM NAME: EVACSIM

BRIEF DESCRIPTION:

EVACSIM (EVACuation SIMulation) analyzes evacuation from all structures during accident scenarios.

CONTACT: Jo Wiklund, A/S Quasar Consultants

Street address: Harbitzalleen 12

City: 0275 Oslo

State:

Postal code:

Country: NORWAY

Telephone: 47-22-73-08-60

COMPUTER: SUN SPARC workstation.

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

X-Windows / SUN OS 4.1

PERIPHERALS REQUIRED:

COST: $13,000 (US)

ITEM NAME: EXTREME

BRIEF DESCRIPTION:

EXTREME is a program for Bayesian statistical analysis of risk data useful for situations where only limited data is available.

CONTACT: Stephen Ramsay c/o EnviroTech Research Limited

Street address: Suite 130 - 100 Collip Circle
U.W.O. Research Park

City: London

State: Ontario

Postal code: N6G 4X8

Country: CANADA

Telephone: (519) 858-5049

COMPUTER: IBM-PC (386 or better with co-processor or equivalent)

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

DOS 5.0 (or better) / spreadsheet software

PERIPHERALS REQUIRED:

Printer (optional)

COST: $2,500 (US)

ITEM NAME: HyperBird (registered name) GIS and Applications Product Family

BRIEF DESCRIPTION:

HyperBird (registered name) Geographic Information System with

* Facility and Land Information Systems
* Network Management Systems
* Environment and Territorial Surveillance

CONTACT: Durr & Partners, Management and GIS Consultants

Street address: 57 Punkhorn Point

City: Mashpee

State: Massachusetts

Postal code: 02649

Country: USA

Telephone: (508) 477-5111

COMPUTER: Apple Macintosh

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

System 7.1

PERIPHERALS REQUIRED:

2 or 3 monitors (1 b/w, 1 or 2 high resolution color), optional scanner, color printer, GPS

COST: $4,900 to $27,000 depending on simulation module

ITEM NAME: MONTY

BRIEF DESCRIPTION:

MONTY is a quantitative risk assessment (QRA) package for industrial sites, pipelines and transportation corridors, providing industrial and societal risk estimates for plant design, insurance, corridor planning and emergency management.

CONTACT: Matthew Hilbert c/o QRA Research

Street address: 79 Blackburn Crescent, RR # 3

City: Komoka

State: Ontario

Postal code: N0l 1R0

Country: CANADA

Telephone: (519) 474-1226

COMPUTER: IBM-PC (386 or better with co-processor or equivalent)

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

DOS 5.0 (or better) / spreadsheet software

PERIPHERALS REQUIRED:

Printer (optional)

COST: $7,500 (US)

ITEM NAME: REMS (Regional Evacuation Modeling Software)

BRIEF DESCRIPTION:

Models area evacuations by using network and transportation models. Estimates evacuation times and road congestion. Animation of simulation. Graphical display of evacuation.

CONTACT: Suleyman Tufekci

Street address: 303 Weil Hall, The University of Florida

City: Gainesville

State: Florida

Postal code: 32611

Country: USA

Telephone: (904) 392-6753

COMPUTER: 386 or higher PC's.

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

DOS based. Microsoft Windows version under development.

PERIPHERALS REQUIRED:

VGA or Super VGA monitor for graphics.

COST: Negotiable.

ITEM NAME: SHELL of the expert system SPRINT.

BRIEF DESCRIPTION:

Creating bases of knowledge and data on impacts along with recommendations for making decisions and diagnosis of situations, using mathematical models.

Email: wdcblm@Sovamsu.sovusa.com

CONTACT: Vyazilov, Eu. D.

Street address: 6, Korolyov St.

City: Obninsk

State:

Postal code: 249020

Country: RUSSIA

Telephone: 0-8439-25676

COMPUTER: IBM-PC AT

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

Microsoft MS-DOS

PERIPHERALS REQUIRED:

2 MB disk storage; 400K on-line storage

COST: $300 (US)

ITEM NAME: Volcano Early Warning System

BRIEF DESCRIPTION:

An early warning system for detection of volcanic eruptions is now available. It utilizes the Argos LEO satellite system for data messaging from remote sensors.

CONTACT: Dr. Peter Griffith

Street address: North American CLS, 9200 Basil Court, # 306

City: Landover

State: Maryland

Postal code: 20785

Country: USA

Telephone: (301) 341-1814

COMPUTER:

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

PERIPHERALS REQUIRED:

COST: Call for quotation.

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COMPUTER:

OPERATING SYSTEM / OTHER SOFTWARE REQUIRED:

PERIPHERALS REQUIRED:

COST: Call for quotation.

AUTHOR INDEX

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